U.S. DEPARTMENT OF COMMERCE
National Technical Information Service
PB80-141484

Codisposal of Municipal Solid Waste and Sewage Sludge An Analysis of Constraints

Gordon Associates, Inc, Washington, DC

Prepared for

Environmental Protection Agency, Washington, DC Office of Solid Waste

1980

PB80-141484

CODISPOSAL OF MUNICIPAL SOLID WASTE AND SEWAGE SLUDGE

An Analysis of Constraints

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U.S. ENVIRONMENTAL PROTECTION AGENCY

1980

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INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

ELIOGRAPHIC DATA
HEET

1. Report No.

2.

3. Recipient's Accession No.
PB80-141484

itle and Subtitle
Codisposal of Municipal Solid Waste and
Sewer Sludge: An Analysis of Constraints

5. Report Date
1980

6.

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8. Performing Organization Rept. No.

Performing Organization Name and Address

Gordian Associates, Inc.
Suite 405
1919 Pennsylvania Avenue, N.W.
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10. Project/Task/Work Unit No.

11. Contract/Grant No.
68-01-4427

2. Sponsoring Organization Name and Address
Resource Recovery Branch
Office of Solid Waste
U.S. EPA
Washington D.C. 20460

13. Type of Report & Period Covered
Analyses

14.

5. Supplementary Notes

6. Abstracts

The Report is an overview of the significient issues confronting the integration of municipal solid waste disposal and municipal sewage sludge disposal. An analysis of the technical, economic and environmental issues of integrated waste disposal (codisposal) facilities is discussed.

17. Key Words and Document Analysis. 17a. Descriptors

Solid Waste
Sewage Sludge
Codisposal
Resource Recovery
Waste to Energy Systems

17b. Identifiers Open-Ended Terms

7c. COSATI Field/Group

vailability Statement
Unlimited

19. Security Class (This Report)
UNCLASSIFIED

21. No. of Pages

20. Security Class (This Page
UNCLASSIFIED

22. Price

This report was prepared by Gordian Associates Inc., Washington, D.C., under contract no. 68-01-4427.

Publication does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of commercial products constitute endorsement by the U.S. Government.

An environmental protection publication (SW-184 c) in the solid waste management series.

ACKNOWLEDGEMENTS

This report was prepared by Dick Baldwin, Tom Barnett, Dick Richards, and Jim Price under the direction of Harvey Gershman of Gordian Associates Inc. Also, Klaus Feindler of Quantum Associates served as a technical consultant on this project. The authors wish to acknowledge the valuable assistance provided by the EPA Project Officer, Dave Sussman and the many members of the solid waste and wastewater treatment industry who contributed time and information to this effort.

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PREFACE

Data on codisposal was scarce or non-existent and had to be gathered from an unusually disparate group of public and private bodies. Work commenced on this project in the summer of 1978 and, for a number of reasons including delays caused by waiting for pertinent Federal regulations to be issued and lengthy review processes, the report was not completed until late 1979.

Unfortunately, it was not possible to update some of the economic data that was gathered at the beginning of the work effort. The reader should note that, as a result, the cost figures presented relate to mid 1978 levels and therefore do not reflect the sometimes significant prices increases of the past year. This timelag is true only for economic data. The information concerning the status of technologies, existing or planned projects, and Federal legislation has all been updated and is current as of December 1979.

The reader should bear in mind that the major purpose of this report is to provide an overview of the significant issues confronting codisposal rather than to detail specific economic or engineering data. In that sense, this report should be a valuable reference document for anyone seeking a better understanding of the codisposal of refuse and sludge.

It should also be noted that EPA's Resource Recovery Branch will soon be issuing updated versions of their "Resource Recovery Plant Implementation: Guides for Municipal Officials" series. The new versions will include a volume on codisposal.

1. INTRODUCTION

1.1 Background

This report was prepared for EPA's Office of Solid Waste under Contract No. 68-01-4427 (Task 14). Its' purpose was to assess the nature and importance of institutional and economic factors associated with the codisposal of municipal solid waste (MSW) and municipal sewage sludge (MSS).

The study effort for the report was evolutionary in its nature, commencing with an analysis of the relative cost of codisposal. This seems a proper starting point, since, for most situations, if codisposal is not economically attractive under some set of conditions, then institutional problems are of no relevance. On the other hand, if there is some cost advantage in codisposal, then institutional issues will warrant close examination in order to separate the significant obstacles from those which will be removed almost reflexively when economic advantage can be shown.

The project examines eight distinct codisposal processes, as well as the single-purpose solid waste and sludge handling processes that would, if used together, comprise codisposal. The processes are:

Codisposal	Single Purpose Solid Waste	Single Purpose Sludge
Sanitary Landfill	Sanitary Landfill	Incineration
Conventional Incineration	Conventional Incineration	Landfill
Sludge Composting	Waterwall Combustion	Heat Drying
RDF in Sludge Incinerator	RDF Dedicated Boiler	Composting
Waterwall Combustion	Modular Incinerator	
Dedicated Boiler	Pyrolysis	
Modular Incinerator		
Pyrolysis		

For each process, the report presents a description and an estimate of capital and operating cost for three scales of operation.

The analysis of relative costs was a problematic exercise, because the available information on costs of wastewater residuals and solid waste handling is replete with poor or conflicting data, and there are a number of areas where relatively little is known regarding process cost. In large part, the literature is intended to serve the needs of project planners who are able to specify narrowly the dimensions of the systems they want to compare. As a result, it is less useful as the basis for developing a set of cost data that is consistent enough for comparison purposes.

A second thrust of study dealt with institutional issues, focusing on three areas: organizational differences between wastewater and solid waste management programs, planning and financing issues, and legal issues. In this separate area, the literature is relatively sparse, so that definite conclusions are not possible. Further, a brief look at several codisposal projects around the country emphasized that institutional issues are as unique and site-specific as engineering issues.

The data developed in the cost analysis served two purposes. First, they enabled a comparison of the relative costs of various codisposal options to be made. Second, they served as input to an assessment of alternative approaches to EPA funding assistance under recent provisions of the Clean Water Act.

In regard to limitations, it should be noted that this study is intended to be highly general. Accordingly, the cost data, as well as the institutional discussion, do not refer to events on the level of a specific project, except for the analysis of funding alternatives. The intent was to provide broad comparisons and conclusions regarding the economic and institutional viability of codisposal. Another limitation is that only municipal wastes are considered in this report, excluding any discussion of the disposal of industrial sludges or solid wastes.

Apart from the limitations in scope, the study is also restricted as to the level to which any single issue could be developed. In particular, this is evident in discussing issues of financing. Many practical problems exist beyond the single question of EPA funding policy. However, it was not possible within the study's time and resource constraints to carry the discussion beyond what is shown in Chapter 3, which compares several financing and cost allocation procedures in a general way, using hypothetical data.

1.2 Highlights of the Report

The following is a brief listing of the major findings of each chapter of the report.

1.2.1 Overview of Codisposal Alternatives (Chapter 2). This section discusses both single purpose and multiple purpose sludge and solid waste handling systems in terms of the criteria that indicate their potential for further use in codisposal projects. Major points are:

- Extent of Use of Given Systems. Landfill is by far the most widely used MSW disposal alternative, but it is perceived as being restricted to some extent in the future by RCRA requirements. Incineration is most widely used for sludge. Of the codisposal processess, thermal methods seem to be the most likely for the future. It is worth noting that the literature indicates landfill codisposal to be a viable process. However, it is not likely to apply in areas where high technology codisposal is being considered.

- Relative Cost of Processes. Landfill is the least expensive for both single and multiple purpose projects. If landfill is prohibited, thermal methods are the next attractive alternative. Thermal codisposal is a high technology option, but it also shows significant scale economies. Our analysis shows that codisposal is competitive with capital-intensive single purpose processes and that it should always be considered.

- Status of Technology. Apart from landfill, the thermal methods of MSW disposal appear to be the best understood. Similarly, for MSS, thermal methods are well known, while the best-developed codisposal options are those which relate to either mass burning of MSW or sludge incineration. Pyrolysis, RDF production, and composting represent the areas with greatest need for technical or economic data development. In any case, technologies are constantly evolving and, in general, more data are needed.

- Future Prospects. EPA expects sludge incineration to grow as a disposal alternative. For MSW, landfills will be able to continue in many parts of the country. However, as energy needs grow and as land-intensive options run out due to future regulation, codisposal should be seen as an attractive alternative. This is particularly true in the populous north eastern seaboard areas where landfill space is scarce and communities are facing the 1981 ban on ocean dumping of sludge, which is their current method.

- Other Issues. Relative rates of MSW and MSS in combination were examined in the report. Based on dry weights, these can range from equal parts sludge and solid waste, up to greater than the 13:1 ratio that indicates equivalent populations. Some processes are more flexible than others, with pyrolysis and waterwall incineration showing the largest range of combinations. In general, however, the optimum rates of combination for most processes indicate that codisposal may not represent a solution to disposal of both waste streams.

- Policy Trends. Pending EPA decisions regarding codisposal financing, landfill regulations under RCA, and individual state positions on exempting resource recovery from "offset" regulations under the 1977 Clean Air Act Amendments will significantly influence the future of codisposal.

1.2.2 Institutional Factors Affecting Codisposal (Chapter 3). Three areas were found to constitute the most significant institutional constraints:

- Organizational and Planning Issues. Because of the inherent and programmatic differences in solid waste and wastewater management, there are many points of significant difference. The major items deal with problems in planning, many of which can be resolved with an overview approach rather than continuing the current emphasis on specific project analysis.

- Financing Issues. The central issue is EPA's policy toward funding. Several alternatives were examined, including one which would not be based solely on formula allocations. In general, it is not felt that EPA's funding policy is a major obstacle, although it could be defined so as to be a more positive incentive.

- Legal Issues. Waste control and interference with private operations are the two major legal problems. These will be dealt with over a period of time as court decisions and new legislation begin to develop a body of law.

1.2.3 Implementation Examples of Codisposal (Chapter 4). The report examines several current examples of codisposal, both successful and otherwise. The data presented are merely objective summaries of the projects, as opposed to analytical case studies. Also included are contemporary reports on the plans of major East Coast ocean dumping communities.

2. OVERVIEW OF CODISPOSAL ALTERNATIVES

In discussing the constraints that might inhibit the broader implementation of codisposal, it is important to frame the discussion in terms of the general viability of the various codisposal alternatives. In planning, these alternatives would initially be tested against standards of technical and economic feasibility. If these tests indicate infeasibility, then no further action would be warranted; the planning process would not be hindered by possible institutional problems. This chapter examines codisposal relative to the most widely used single-purpose sludge and solid waste disposal practices. Its intent is to determine the approximate points at which codisposal should be considered along with single-purpose alternatives.

This chapter describes single-purpose sludge and solid waste handling options and provides estimates of the cost per ton of waste material disposed by each method. Codisposal processes are also examined, along with estimates of the cost per ton for disposal. In addition to cost estimates, the parallel issues of financing, regulation, restrictions, and status of the technology are discussed. These data are all drawn together to indicate the boundaries of cost and feasibility where codisposal might be a viable option.

The discussions of processes and disposal costs for both sludge and solid waste are based on schematic, generalized processes. Cost estimates for comparison among system options were developed by drawing upon the broad estimates that can be found in the currently available literature. The resulting cost data are approximate, but they have been adjusted to the extent possible to eliminate differences in assumed unit costs, amortization terms and price levels. The method of cost derivation is discussed in detail in this chapter and in Appendices A and B.

2.1 Municipal Solid Waste

2.1.1 Municipal Solid Waste Disposal Alternatives. Seven major alternatives for the disposal of municipal solid waste (MSW) are discussed in this study, emphasizing those processes that have the potential for compatibility with sludge disposal. The seven alternatives which are discussed below are: sanitary landfilling, conventional (refractory-wall) incineration, waterwall combustion, RDF processing, dedicated boilers, modular incinerators with energy recovery, and pyrolysis. In addition to describing each process, reference has been made to existing or planned examples, relative cost data, the status of technology, external constraints, and future prospects. Relative costs are summarized in Table 2.

Sanitary Landfills. This method of disposal handles over 90 percent of the nation's solid waste stream. Its predominance can be accounted for by the fact that in most cases landfilling is the easiest, most reliable, and cheapest alternative.

A variety of landfilling methods may be followed, depending primarily on the type and volume of the solid wastes, site hydrology and the availability of cover material. In general, the process consists of spreading the solid waste in thin, compacted layers over a prescribed area of land, and then covering it each day with the required amount of cover material. Usually the depth and frequency of cover material are established by state or local regulation.

Capital and operating costs are closely tied to site factors and operating procedures. As a result, landfill disposal systems display wide variations in cost. One of the primary variables is the cost of land, which ranges from nominal lease charges in some rural areas to the high values found in many urban or suburban communities.

Many of the landfill studies examined as sources for this report showed lower average ton disposal costs than those developed here. This was apparently due to a preponderance of low cost rural landfills in areas that would be unlikely to have coincident sludge disposal problems. Thus, the emphasis in this study was placed on the higher landfill prices being paid in urban areas.

Landfills are required for the ultimate disposal of residues no matter what solid waste management system is employed. Thus, they span the full spectrum of capacity in tons per day. While there is no optimum size, it is generally recognized that there are economies of scale to be gained from consolidating into larger operations, up to the point of collection cost constraints.

The cost estimates in this report are based on landfilling with unprocessed waste. Any additional costs or savings from shredding and baling were not considered. It is not clear from the available data whether these processes add to or subtract from the net cost of conventional landfilling, since their relative costs must be determined for specific projects. However, two points of significance for compatibility with sludge disposal should be noted: shredding tends to increase the absorptive capacity of MSW, while baling reduces it.

Financing of landfills can take many forms, depending on the scale of the project. The relatively low level of capital required, the typically public ownership, and the low risk nature of the process make funding through general obligation bonds the most popular approach. Many smalller landfills are financed entirely on a "pay as you go basis," out of current revenue from general taxation. In our estimates, a capitial amortization period of ten years was used since it is difficult to procure an area of land with sufficient capacity for longer than that given the resistant climate of prevailing public opinion.

At the moment, landfilling appears likely to be the disposal method most directly affected by the requirements of the 1976 Resource Conservation and Recovery Act (RCRA). Section 4004 of the Act stipulates that specific criteria for acceptable landfills will be promulgated by EPA. These criteria have recently been published (Sept. 1979) and it appears that their effect will be to raise the cost of landfilling by imposing stricter standards, especially for methane and leachate control. Landfilling will probably continue to be the predominant method of waste disposal, primarily because it will contine to be the cheapest alternative for much of the nation's waste. Also, all of the more sophisticated disposal alternatives leave some degree of residue that must ultimately be disposed of in a sanitary landfill.

Incineration. This term covers a variety of specific processes involving waste volume reduction through high temperature oxidation and, in many systems, recovery of the energy released. Incineration systems which recover materials and/or energy are discussed in subsequent sections. The present discussion is concerned with those systems which incinerate waste for the purpose of volume reduction. The incineration process is generally very effective; reduction in excess of 90 percent by volume can often be achieved. This has the effect of extending the landfill life by approximately tenfold.

In a typical system (see Appendix A, Table A-2 for a schematic diagram) waste is deposited in an unloading and storage area. A furnace feed system passes the waste to a combustion chamber where air is supplied in the quantitites required for thorough combustion. Exhaust stacks must be equipped with a pollution control device to clean up emissions and a means must be provided for removing the residue.

Modular incinerators also perform as volume reduction systems, but on a somewhat different principle. These units are prefabricated and shipped to the site and consequently are suitable for smaller volume of waste (5 to 30 TPD per unit), although several may be co-located to achieve capacities of up to 150 TPD.

The generalized system consists of a batch fed primary chamber where raw MSW is combusted, usually under starved air conditions. The resulting volatile gases are burned in a secondary combustion chamber before being fed to an air pollution control device. If combustion temperatures are kept high enough, emission control is relatively easy and inexpensive.

Both of the systems described above, operate as mass burning incinerators, which do not process the waste prior to materials recovery. Extremely large or dangerous objects may be sorted prior to incineration, but the remainder of the non-combustibles are landfilled as part of the residue. Both systems also require relatively small amounts of fossil fuel for start-up and maintaining proper operating temperatures.

The system costs shown in Table 2 do not include any allowance for residue materials recovery, although it is technically possible.* "Back end" materials recovery is considered to be so economically questionable at this time that there is not enough activity to warrant its inclusion. It can be ssen from Table 2 that both systems have comparable costs, but at significant scale differences, with an average value of $12.50 for refractory wall (500 TPD) compared to $12.00 for modular incinerators (50 TPD). When compared at their only commonly-calculated capacity of 100 TPD, the modular system is more attractive: $9 per ton vs. $15 per ton. The much higher excess air requirements of refractory wall incinerators and the resultant air pollution control costs are a significant aspect of the higher costs.

A recent study of emissions from refractory type incinerators concluded that not only are suspended particulates a problem, but also "that incinerators are the major source of airborne Cd, Zn, Sb and possibly, Sn and Ag in many areas."** The increasing concern over the detrimental health effects of these substances may lead to more stringent controls and therefore higher costs for this disposal approach.

Modular units, operating on a starved air principle, generally have less difficulty in meeting emission standards with less costly scrubber-type devices. Further, the systems can be adapted to numerous smaller communities with landfill problems, for whom high technology alternatives would be inefficient.

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*A summary of MSW economics is shown in Table 2 on page 19.

**Greenberg, Zollen, and Gordon, "Composition and size distribution of particles released in refuse incineration."

In volume reduction systems such as these, no revenues are generated and operation represents a cost to be offset or covered entirely by tipping fees. Financing can often be accomplished through the public pwnership options of short term bank borrowing, general obligation bonds, or leasing from or contracting with private firms. The method selected depends on the amount of capital required and the community's financial condition. Contracting with a private firm may well prove to be more efficient, regardless of the community's financial situation.

Mass Burning Waterwall Combustion Systems. A waterwall furnace is a combustion chamber whose walls are lined with tubes containing circulating water. The water recovers heat radiated from the burning waste to be used in steam generation. Combustion takes place on grates of varying design, which keep the waste moving while allowing air to circulate for thorough combustion. Combustion gases are passed through air pollution control devices (usually electrostatic precipitators) prior to venting (A generalized system is shown in Appendix A, Table A-3). This type of furnace has become the clear favorite in the large scale burning of solid waste because of its relative ease of maintenance and high efficiency in heat transfer.

A listing of major existing or planned resource recovery facilities is shown in Table 1. At present, the smallest operating waterwall combustion facility in the U.S. is the Navy's 360 TPD capacity system in Norfolk, Virginia. A smaller facility is planned in Hampton, Virginia (200 TPD). Most existing or planned facilities are larger in order to capture the economies of scale evident from Table 2.

This system discussion also assumes that no front end processing occurs (although several have shredders for oversize objects), and no back end recovery occurs; therefore, no materials recovery revenues are realized. As noted earlier, revenues from steam generation are quite variable. An important determinant of a steam price is whether the steam can be supplied on a "firm" basis, as with most fossil fuel produced steam, or if at a lower price, an interruptible agreement is possible. In most cases, MSW generated steam is sold to users who already possess steam producing capabilities or who must build standby systems to ensure production, and therefore need an incentive to purchase power from a new source. The incentive is usually in the form of a reduced price compared to the alternative fossil fuel price. For users with their own steam generation capabilities such as utilities, MSW steam is usually sold as supplementary power at reduced peak load prices compared to the higher base load rates. Current agreements by

TABLE 1

CURRENT STATUS OF MAJOR RESOURCE RECOVERY PROJECTS*

DISPOSAL ALTERNATIVES†	LOCATION	ORIGINAL OR ESTIMATED CAPITAL COST ($ X 1000)	CAPACITY	STATUS
MASS INCINERATION--WATERWALL COMBUSTION	Harrisburg, PA	12,800	720 TPD	Operational since 1972
	Saugus, MA	61,000	1200 TPD	Operational since 1975
	Nashville, TN	32,600	720 TPD	Operational since 1974
	Norfolk, VA	5,537	360 TPD	Operational since 1967
	Braintree, MA	4,850	240 TPD	Operational since 1971‡
	Chicago, IL	39,100	1600 TPD	Operational since 1971
REFUSED DERIVED FUEL - Fluff	Lane County, OR	2,100	500 TPD	(in shakedown) Operational by Fall 1978
	Chicago, IL	19,000	1000 TPD	(in shakedown) Full Production by Fall 1978
	Baltimore, MD	8,400	600-1500 TPD	Testing
	Ames, IA	7,600	200 TPD	Operational since 1975
	Milwaukee, WI	18,000	1600 TPD	(in shakedown) Partially Operational
	Monroe County, NY	32,400	2000 TPD	Startup by 1979
	New Orleans, LA	7,750	700 TPD	In shakedown
- Dust	Bridgeport, CT	53,000	1800 TPD	Operational in 1979
	E. Bridgewater, MA	10,000-12,000	1200 TPD	Testing
	Newark, NJ	70,000	3000 TPD	Operational in 1980
- Wet	Franklin, OH	5,440	150 TPD	Operational since 1971
	Hempstead, NY	73,000	2000 TPD	Testing
	Dade County, FL	60,000	3000 TPD	Startup scheduled
- Densified				
DEDICATED BOILERS	Akron, OH	46,000	1000 TPD	Operational in 1980
	E. Hamilton, ONT	9,000	600 TPD	Operating at 300 TPD
	Niagara Falls, NY	65,000	2200 TPD	Operational in 1980
MODULAR INCINERATORS	Blytheville, AR	976	50 TPD	Operational since 1975
	Groveton, NH	305	30 TPD	Operational since 1975
	Salem, VA	-	100 TPD	In shakedown
	Siloam Springs, AR	501	19 TPD	Operating since 1975
	Auburn, ME	-	150 TPD	In final negotiations
	N. Little Rock, AR	-	100 TPD	
PYROLYSIS - Landgard	Baltimore, MD	29,200	600 TPD	Re-started Summer 1979
- Torrax	Luxembourg and France	-	-	
- Purox	S. Charleston, W VA	17,290	200 TPD	Operational since 1974
- Garret	San Diego, CA	15,500	200 TPD	Demonstration Plant, now closed

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* Source: Gordian Associates Inc.

† Landfill and/or incineration without resource recovery are found in most major cities and many other areas. Capital and capacities vary widely as discussed in text.

‡ Recently shut down; see text.

MSW steam purchasers are in the range of $2.75 to $3.50 per 1000 lb. of steam, which is about $0.50 to $1.00 below in-house generation costs.* For this study an average price of $3.00 per 1000 lb. steam was used. Steam revenues per input ton of MSW are based on the above price multiplied by the amount of steam produced per input ton. Current waterwall boilers can produce up to 6000 lb. steam per ton of MSW, therefore earning $18.00/ton from the sale of steam.

Due to the large capital requirements and revenue producing nature of this system, the most common form of financing is through either municipal or industrial revenue bonds. The method selected depends on who owns and operates the facility (if public, then municipal revenue bonds), the amount of capital required, and alternative sources of that capital. For large, institutionally complex projects, a combination of approaches will often be employed.

Mass burning waterwall technology in general is well developed, with the European waterwall experience paving the way for U.S. expansion of that process. European system manufacturers such as VKW, Von Roll, and Widmer-Ernst have a total of over 100 facilities in operation in Europe. In fact, most waterwall processes in this country involve American franchises for a European manufacturer. For mass burning systems, slagging and corrosion of water tubes, along with larger than expected levels of residue have created some difficulty, but the biggest problem in early U.S. plants has been meeting stringent air quality standards. Modern electrostatic precipitators have proven to be capable of meeting these requirements.

The short term future for waterwall incineration looks promising. The technology is well developed and the economics appear to be competitive with other disposal options. Consequently, many communities (see Table 1) are commiting themselves to the major investment which this process requires.

Refuse Derived Fuel (RDF) Processing. The basic RDF system processes municipal solid waste to produce a transportable supplemental solid fuel for use in fossil fuel fired energy systems. This fuel product currently is made in several forms, but the processing approach is very similar for most systems (Black Clawson's hydra-pulping being a notable exception). A represntative system employing a composite of the state-of-the-art processes is shown in Appendix A, Table A-6.

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*Gordian Associates, "Overcoming Institutional Barriers to Solid Waste Utilization As an Energy Source".

Basic full materials recovery systems such as this employ a complex processing train to separate ferrous metals, aluminum, and glass.* Approximately 75 percent by weight of the incoming solid waste exits the system as RDF, consisting mainly of paper and light organics, and containing 5500-6500 Btus/lb. The initial trommeling stage and secondary shredding step shown in Appendix A are the most recent attempts to reduce maintenance costs and increase materials recovery while producing a cleaner burning fuel.

The form of the end product RDF is the major distinguishing feature among systems. The most common type is fluff-RDF, which results from the processing described up to this point. The best examples of this system are found in Ames, Iowa, St. Louis, and Americology's plant in Milwaukee. "Hydra-pulping" also produces fluff-RDF. The process has been demonstrated at Franklin, Ohio; a large scale plant is operational at Hempstead, New York and planned for Dade County, Florida.

Another promising form for the final product to assume is termed dust-RDF. In this process, the shredded waster undergoes a further step which coats the light portion with an embrittling agent. This allows the waste to be fragmented into tiny particles which have a higher Btu per pound value and burn more evenly than standard fluff-RDF. The main proponent of this system is CEA/OXY, with a plant in shakedown in Bridgeport, Connecticut and planned for Newark, New Jersey.

The third approach to RDF processes the shredder waste through an additional stage which densifies the product into pellets of varying size and shape. This "densified RDF" is designed to be of the same general size and consistency as crushed coal, which simplifies handling and feeding adaptions for conventional coalfired boilers. The process has been demonstrated at the NCRR facility in Washington, D.C. and is also being tested by Detroit Edison. The design of the end product RDF is dependent on the specific type of boiler that it will fuel. The minimization of adaptation costs is generally the objective of this process.

There is significant variance in the capital required for the alternative processes. Fluff-RDF is the least expensive system to construct, averaging $17,000/per daily design ton of capacity, with wet, densified, and dust systems ranging from $2000 to $5000 more per daily design ton.

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*This study assumes that revenues from materials recovery will be about $3.40 per input of MSW. For details on this assumption. see Section 2.1.2

Revenues from the sale of RDF are extremely variable and dependent on the following factors.

- The energy recovery efficiency of the process - i.e., the BTU content of the RDF expressed as a percentage of the Btus available in the input MSW. The efficiencies used here are based on EPA data.*
- The price of the alternative fossil fuel which is currently being used or would be used in place of the RDF. In most instances, this fuel is coal since RDF is most compatible with coal fired systems. The price assumed here is a national average figure of $1.00/Mbtus.**
- The degree of difficulty which energy users will have in converting their systems to burn RDF. This can be expressed in terms of a discount in the price which RDF would commmand if compared directly with fossil fuel on a Btu basis. This "handling charge" varies with the physical form of the RDF. Since pelletized RDF is designed to be compatible with crushed coal feed systems, the discount is smaller. Dust-RDF also can easily be adapted to pulverized coal burning boilers at comparatively little cost. These variations are reflected in the energy revenues per ton of MSW shown in Table A-4 through A-6 in Appendix A.

As with waterwall systems, RDF systems are most often financed through revenue bonds. However, almost as many current or proposed systems utilize state or local general obligation (GO) bonds for their funding. The amount of funding available through GO bonds is limited to statutory debt ceilings which may be a severe constraint for communities already at or near that mark. GO bonds also require voter approval. But, unlike revenue bonds, which are subject to the scrutiny of the underwriters, GO bonds do not require feasibility studies. This often means that a project must be more clearly defined and well researched in order for revenue bond sales to be successful.

The technology of producing RDF must still be considered developmental at this point. Although a number of pilot and demonstration plants have been set up and many full scale facilities are in the planning and construction stages, there are very few commercially operational RDF systems in existence. Consequently, the widespread endorsement of this approach is being withheld for fear that newer technology will render recently acquired systems obsolete. There have also been technical problems involving the materials recovery process for aluminum and glass, the extreme wear and downtime of shredders, and the handling of RDF. Two areas are especially troublesome: RDF is proving difficult to store due to its varying moisture content, microbial decomposition and potential fire and explosion hazard; experience to date has shown that process lines involving shredders must find ways to contend with the threat of explosions. This danger has increased the popularity of trommeling as an alternative or supplement to shredding. To ensure continuous operation in the face of frequent breakdowns, costly redundancy must be built into the system. Special consideration must also be given to the compatibility of RDF with boilers and their present fossil fuels. Current results indicate some minor problems with slagging and corrosion and more difficult problems of handling increased ash levels.

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*U.S. EPA, "Technologies; Resource Recovery Plant Implementation", p. 23

**U.S. FEA, Monthy Energy Review, August 1978.

At present, federal and state regulations exert few constraints on RDF facilities. As with all high technology systems, emission standards necessitate elaborate and expensive pollution control equipment on the stack of the fuel user. The study of incinerator emissions cited earlier* also noted that RDF burning may not generate the same level of noxious pollutants as mass burning because the removal of the metal and glass laden fraction of the waste stream may assist in reducing certain emissions.

The future for RDF systems will be shaped mainly by the success or failure of the technology to develop a reliable, easily used fuel which is adaptable to many systems. The critical element for success will be the development of a large scale market for the product. The widespread public endorsement of this approach as environmentally sound has been a boon to its development. EPA predicts the operation of 40 to 70 resource recovery plants by 1985, many of which will be RDF producers in some form.** So, in spite of technological and market uncertainties, the RDF solid waste disposal alternative seems assured of at least a promising short-term future. Long term predictions depend, again, on records yet to be established. If fossil fuel prices escalate as expected, the process of producing energy from waste will inevitably become more attractive. Note that, currently, RDF and sludge combustion is one of several major focal points of codisposal interest.

Dedicated Boilers. There are many different system approaches which can be grouped under the heading of dedicated boilers. In the generalized system used in this study, incoming waste is trommeled, shredded, passed through materials separation processes, air classified and often re-trommelled or reshredded before entering a furnace chamber designed to fire RDF exclusively. Of special note is the Black Clawson hydra-pulping processing approach which differs from this description in that the incoming waste is wetted and processed in basically the same manner as above, except as a slurry. Not only can the RDF be produced through a variety of processes, but the boiler as well can fire the fuel in several different configurations. For this discussion a generalized system is assumed, consisting of a full materials recovery, fluff RDF-process train combined with a semi-suspension combusion unit using a waste heat boiler.

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*Greenberg, Zollen and Gordon, op. cit.

**U.S. EPA, Solid Waste Facts, May 1978.

Table A-7 in Appendix A shows annual costs broken down into RDF processing costs and boiler costs. The average capital requirement is $35,000 per ton of daily design capacity, with $14,000 going for the RDF train and the remaining $21,000 for the boiler system.

Materials and energy revenues are based on the same assumptions as for the earlier RDF and waterwall systems, respectively. Steam is again assumed to be produced at 6000 lb. per input ton of MSW and sells for $3.00/1000 lb., generating revenues per ton of $18.00. Steam revenues may be slightly understated since newer semi-suspension boilers are capable of generating up to 8000 lb. of steam per input ton of MSW, utilizing much lower rates of excess air than comparable mass burning waterwall systems (30 - 50 percent vs. 100 - 150 percent). This increased efficiency may yield higher revenues but, as the evidence to date is not clear, no differences are assumed here.

Operations and maintenace costs are also somewhat speculative since the documented data are limited. The figures used here are higher than many estimates to ensure a conservative net cost figure that is more in line with the limited historical data from North America's only large-scale operational dedicated boiler facility in Hamilton, Ontario.*

Dedicated boiler systems are subject to the same environmental constraints as waterwall and RDF systems. There are no major impediments to developments, other than ensuring that air quality standards are maintained, and building the system reliability that major markets demand.

The universal adaptability of steam as an energy product is a distinct advantage for systems like waterwall incinerators and dedicated boilers. This eliminates costly conversions for the buyer, but also means that the MSW processing facility and steam purchaser must be co-located (within two miles of each other), since steam cannot be economically conveyed over much distance.

Modular Incinerators with Energy Recovery. Modular incinerator (MI) systems which recover energy can be considered as a case by themselves. The process is operational in North Little Rock, Siloam Springs and Blytheville, Arkansas; Groveton, New Hampshire; Crossville, Tennessee; and Salem, Virginia; with numerous other community systems in the planning stages. As discussed earlier, this modular approach is most suitable for small waste streams. The energy recovery system is fundamentally the same as for the earlier-described volume reduction process, except that a waste heat boiler is installed to capture the heat released in the flue gases from the secondary combustion chamber (see Appendix A, Table A-8). Energy is recovered in the form of steam for sale to nearby users.

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*Estimates of operating costs for the Akron and Niagara facilities appear to be optimistic in view of the Hamilton costs.

The average capital cost for this system is $24,000 per daily design ton of capacity, based on an average capacity of 50 TPD. No materials recovery is assumed from this system and steam revenues are calculated on a different basis than for the larger waterwall and dedicated boiler systems. Modular combustion units have been generally less efficient than the large scale systems, averaging around 4000 lb. steam per ton input of MSW. However, newer units are more efficient, approaching the efficiencies of the waterwall units. Also, due to their batch-fed nature and relatively small scale, MI steam contracts are often made on an interruptible basis. This fact, coupled with the user's sunk capital in existing in-house steam systems, necessitates a substantial price discount to provide an incentive for steam buyers. A review of current sources* shows this discount to average approximately 25 percent lower than comparable fossil fuel derived steam prices.

Existing systems report financing methods which encompass the full range of possible options. The small size and relatively low level of capital required place modular incinerator systems more within reach of private industry funding. There are several instances where the private steam user is involved in the financing process to a significant extent. However, most systems are publicly owned and operated, and consequently have used current revenues, GO or municipal revenue bonds as the source of funding.

Pyrolysis. The pyrolysis of solid wastes refers to the thermal decomposition of wastes in the absence or near absence of oxygen. It differs from incineration in that it is endothermic rather than exothermic. The processes currently under development use the potential energy contained in the waste to provide the heat absorbed during the pyrolysis itself and recover the remaining energy in the form of steam or a gaseous or liquid fuel.

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*Steam contracts for the facilities at Salem, VA, Auburn, ME and published data from Siloam Springs, AR. This discount is comparable to the waterwall and dedicated boiler pricing arrangement.

A representative system is difficult to define since there are currently no commercially operational pyrolysis plants in the U.S. However, most of the systems have in common a pre-processing system, a pyrolysis chamber, a fuel product, air pollution control equipment, and some form of materials recovery (see Appendix A, Table A-9).

The different systems currently being developed work under these same principles with slightly different end products. There are four major processes under development: The Baltimore City "Landgard" system, which produces steam through combustion of low Btu pyrolysis gases; the Andco Torrax System (operational in Luxembourg, France, and Germany) is similar to the Landgard process except that heat from low Btu gases is recycled to pyrolyze the incoming waste; the Union Carbide Purox System (Charleston, West Virginia) which utilizes small amounts of pure oxygen to combust some of the waste, generate the heat necessary to pyrolize the rest of the wastes and produce a medium Btu gas for use as fuel; and the Occidental Flash Pyrolysis system (San Diego) which processes the waste to produce dust-RDF, which is pyrolized using by-products of previous reactions. The product is a gas which is cooled to a liquid, oil-like fuel.

The different approaches to pyrolysis have enough points in common to be grouped together into a generalized system for the purposes of this discussion. Since the technology is currently practiced on such a limited scale, the cost and revenue averages presented here for different sized facilities are especially tentative.

The average capital cost per daily design ton of capacity of a "representative" system is $39,000, with the Torrax system costing the least ($29,000) and the Purox approach topping the range at $47,000. This difference can be attributed to the lack of MSW processing required for the Torrax system and the need for an oxygen generating source for the Purox.

Revenues from materials and energy recovery vary to some extent with the specifics of each system. The individual values were averaged to arrive at the figures shown in Table 2. All systems (except Torrax) recover at least ferrous metals, so the $1.50 per input ton value assumed earlier for materials recovery was used. Also, pyrolysis systems produce a residue which has peculiar characteristics with potential for revenue as a road bed material. The level of revenues that can be expected from the sale of this material is not well documented; a net value of $1 per ton of residue was used here. This translates to approximately $0.20 per input ton of MSW.

The revenues available from energy recovery are derived from the sale of pyrolysis fuel products; either gas of varying Btu content or a liquid oil-type substance. The dollar value per input ton of MSW was determined on the basis of the reported Btu contents of those fuel products compared to the national average price per million Btus of the comparable fossil fuel product. In using these fuels, the purchaser incurs fuel handling adaptation costs analogous to those discussed for steam sales. This cost is represented by an average 10 percent discount from the comparable fossil fuel price which results in the $9.00 per input ton MSW value from energy revenues shown in Table 2. Note that this discount may not be large enough if the gas has to be cleaned to pipeline quality or if very significant fuel burning adjustments are required.

The biggest unknown factor associated with pyrolysis is the status of the technology itself. Each of the proposed systems has encountered an array of fundamental problems which have forced delays, restarts and significant shifts in approach. Communities and vendors are understandably reluctant to commit a major investment to a technology that is clearly still so developmental. It should be noted that several of these systems have been tested utilizing sewage sludge in the pyrolytic reaction and that this technology appears to be compatible with codisposal.

2.1.2 Cost Estimates for Municipal Solid Waste Disposal. Table 2 shows the estimated costs for each process based on a compendium of the most current data available. Historical data were used whenever possible and published estimates were used where actual data are not yet available. Much of the information came from the centralized data files of EPA's Resource Recovery Branch and the National Center for Resource Recovery. All capital cost estimates were brought forward to March 1978 by using the Engineering News Record construction cost index (March 1978 = 2693). Amortized capital costs were made comparable by using a standard 7 percent interest rate and a 20 year amortization period. The data were then grouped by disposal process type, and average per-ton values were derived. A range of 800 to 1200 TPD capacity was used since 80 percent of the available data were for facilities of that size.

Capital costs are fairly well documented; operating cost estimates are based on less reliable data. The "Gross Costs" shown include operating and maintenace costs based on averages of available data. There are numerous documented examples of the costs of constructing a facility, but shakedown-related problems and long construction time lags have prevented the development of as large a body of representative operating cost information. Furthermore, none of the operations data can be presumed to represent the cost of a system operating at its optimum level. In fact, there seems to be an emerging record of systems being over-designed. Anticipated solid waste streams in some cases have not materialized, so that operating costs per ton are

TABLE 2

SUMMARY OF MSW ECONOMICS*

DISPOSAL ALTERNATIVES	CAPITAL COSTS	GROSS COSTS		REVENUE			NET COSTS	ESTIMATES FOR THREE CAPACITIES				
	$/design ton	Range $/ton	Average $/ton	Range $/ton	Avg. $/ton Materials	Avg. $/ton Energy	Average $/ton	Capacity	Capital $/in Thousands	Average Cost $/ton	Revenue Value $/ton	Net Cost $/ton
LANDFILL	22% of total annual cost	1.5-20.00	6.00	N.A.	N.A.	N.A.	6.00	100 TPD	385	8.00	N.A.	8.00
								400 TPD	1,185	6.00	N.A.	6.00
								1000 TPD	2,400	5.00	N.A.	5.00
INCINERATION Refractory	7,000-25,000	8.00-15.00	12.50	N.A.	N.A.	N.A.	12.50	100 TPD	1,500	15.00	N.A.	15.00
								400 TPD	3,200	12.00	N.A.	12.00
								1000 TPD	6,500	10.00	N.A.	10.00
Modular	12,000-24,000	8.00-18.00	12.00	N.A.	N.A.	N.A.	12.00	10 TPD	225	16.00	N.A.	16.00
								50 TPD	750	12.00	N.A.	12.00
								100 TPD	1,250	9.00	N.A.	9.00
RESOURCE RECOVERY Waterwall Incineration	20,000-51,500	13.00-38.00	25.00	7.00-30.00	18.00	N.A.	7.00	250 TPD	12,200	31.00	18.00	13.00
								400 TPD	17,000	29.00	18.00	11.00
								1000 TPD	31,000	25.00	18.00	7.00
RDF Representative System	7,000-32,000	12.00-22.00	17.00	.90-16.30	3.40	4.60	9.00	250 TPD	6,750	22.00	8.00	14.00
								400 TPD	8,800	20.00	8.00	12.00
								1000 TPD	17,000	17.00	8.00	9.00
DEDICATED BOILERS	24,000-48,000	18.00-40.00	31.00	7.90-30.80	3.40	18.00	9.60	250 TPD	13,000	40.00	21.40	18.60
								400 TPD	16,750	34.00	21.40	12.60
								1000 TPD	32,000	30.00	21.40	8.60
INCINERATION Modular	20,000-30,000	2.00-22.00	15.50	6.00-15.00	N.A.	9.00	6.50	10 TPD	360	20.50	9.00	11.50
								50 TPD	1,250	16.50	9.00	7.50
								100 TPD	2,000	14.00	9.00	5.00
PYROLYSIS Representative System	20,000-50,000	15.00-40.00	24.00	5.00-22.00	1.70	9.00	13.30	250 TPD	12,500	32.00	10.70	21.30
								400 TPD	16,000	28.00	10.70	17.30
								1000 TPD	33,600	24.00	10.70	13.30

* Source: Gordian Associates Inc.

probably higher than expected. A good example of this is found in the Hamilton, Ontario, dedicated boiler project, which was designed to process 600 TPD but is currently averaging only 150 TPD. This disparity has had the effect of raising per-ton costs from the predicted $15.00 per ton to over $46.00 per ton. Most of the additional cost ($22.00) is due to charging fixed costs, such as capital amortization, against a lower daily throughput.

Capital costs in most cases include all contingency, engineering, legal and administrative costs, as well as bond acquisition, site preparation and construction costs. Most operations are also designed with some measure of redundancy (less than total in most cases) built into the processing streams. For most of the system categories presented in Table 2, the range of unit costs is broad.. This appears to be the result of two factors: one is the small number of resource recovery facilities in actual operation, the other is the site-specific nature of most solid waste disposal costs and revenues. The data base for solid waste disposal costs is simply not yet broad enough for reliable generalized economic determination. It should be recognized that these data are used only as a reference point for the comparisons essential to this study.

The data with the greatest degree of variation are for revenues from the sale of recovered materials or energy. The range of values was determined from the referenced sources, but the average revenues were adjusted based on Gordian's experience with existing markets. Average material revenues were derived using EPA data for waste stream composition and recovery probabilities, applied with our best judgement as to prices for the recovered products at the point of origin. For all materials recovery systems, the average revenues are determined as shown in Table 3.

For this study, all materials recovery systems are assumed to be full front end recovery, using state-of-the-art processes. The percentages and prices shown in Table 3 could be realized by recovering ferrous metals magnetically, aluminum through the use of eddy current separators, and glass via froth flotation. While not all recovery systems recover each of these materials in this manner, the trend is toward incorporating these technologies as possible revenue generators should market conditions become favorable. Energy revenues are keyed to the latest available* national values for the price per million Btus of competing fossil fuels adjusted according to typical conversion efficiencies for solid waste disposal processes.

The result of the cost and revenue computations is shown in Table 2 as the average net cost per ton. This number does not include any revenues from tipping fees. This net cost in effect represents the fee that would have to be charged if the process were to break even.

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*February 1978 price data as shown in U.S. FEA, Monthly Energy Review, August 1978.

In reality, tipping fees are often determined more by local influences or by the costs of alternative disposal options. For this reason, no tipping fee is specified here; but, as the net figure is presented in terms of dollars per input ton, it is easy to calculate the effect of varying charges directly.

TABLE 3

REVENUES FROM MATERIALS RECOVERY

Material	% of Waste Stream	% Recovery Possible	Market Value $/ton F.O.B.* Recovery Facilities	$/ton MSW
Ferrous Metal	7	90	25	1.60
Aluminum	0.7	60	200	0.85
Glass	9	70	15	0.95
TOTAL				3.40

Costs and revenues have been estimated for three different size facilities. As a result of the paucity of data noted above, the estimates for each process size include an error margin on the order of ± 30 percent. The estimates were made by plotting documented costs for varying size facilities and estimating a curve relating cost per ton to the scale of operations. These curves were adjusted with data drawn from independent studies of apparent economies of scale in solid waste disposal. The resulting values are in general agreement with data developed by NCRR.*

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*Higher values are often reported but they usually reflect the price obtainable at the buyer's facility, neglecting costs of transportation. Also, recovered materials are generally of poor quality and command a lower than premium price. These figures represent Gordian's assessment of realistic current market values.

Since most current or planned facilities are large (in the 1000 TPD range), the estimated cost curve is more clearly defined in that range; costs for smaller facilities are less reliable. Three different facility sizes were selected to provide a range of representative values that would be appropriate to most communities where these disposal systems would be applicable. The capacities for most processes are 250, 400 and 1000 TPD. The lower limit is based on the generally accepted size below which capital intensive resource recovery systems become impractical. The upper limit was set because economies of scale for most systems are not significant beyond 1000 TPD. However, these sizes could not be applied to all processes. These deviations were noted in the preceding process descriptions.

System economics are influenced by the method of financing selected. The typical public/private financing alternatives are well documented and are presented in Table 4 along with a range of representative interest rates. Capital costs in this study have been included in annual costs by amortizing over 20 years at 7 percent. This interest rate is felt to be indicative of public ownership of the facility, which is the case for the majority of existing or planned solid waste disposal activities. However, a significant trend is evident in that some resource recovery systems are being developed through full service procurement approaches which result in private ownership and operation.

Federal funding can play an important role in financing a solid waste disposal facility, currently done through two major source agencies, EPA and DOE. Conventional waste disposal (i.e., non-resource recovery) does not qualify for most of the federal funding available. At present, funding from EPA is concentrated on resource recovery or source separation programs; although money has been available in the past for the construction of demonstration projects, current EPA policy is to limit funding to the project planning stages.

Under the "President's Urban Policy Program" now being implemented, up to 75 percent of the costs incurred prior to design and construction may be eligible for EPA funding. This program provides $15 million for this purpose in FY '79, as "implementation"

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*NCRR Bulletin, Spring 1975, p. 43, fig. 2.

TABLE 4

FINANCING OPTIONS*

Financing Method	Public Ownership			Private Ownership		
	Financing Instrument	Maximum Amount	Interest Rate (%)	Financing Instrument	Maximum Amount	Interest Rate (%)
"Pay As You Go"	Current Revenues	$100,000(?)	--	Current Revenues	$100,000(?)	--
Borrowing	Short-term Bank Borrowing	$500,000	14-15%	Short-term Bank Borrowing	$500,000	14-15%
	General Obligation Bonds	Limited by municipality debt ceiling	6-8%	Stock sales	Unlimited	--
	Municipal Revenue Bonds	Unlimited	6½-8½%	Corporate Bonds	Unlimited	10.5-12%
Leasing	Simple Lease (Govt. leases privately-owned facility)	--	(Lease Rates - 15-20% of cap. costs)	Industrial Revenue Bonds	Unlimited	7-9%
				Pollution Control Bonds	Unlimited	7-9%
				Leveraged Leasing	Unlimited	6-8%

* Source: Gordian Associates Inc.

grants to states and local governments. Also, under the provisions of RCRA, technical assistance for solid waste problems is available through the EPA regional "panels teams." DOE has awarded planning money under a similar program for projects which recover energy from municipal solid waste. At this writing , a loan guarantee program is also under consideration by DOE.

2.2 Municipal Sewage Sludge

2.2.1 Sludge Disposal Alternatives. The removal of pollutants from raw municipal wastewater produces a stream of residual solid material (sludge) consisting generally of the solid organic and inorganic impurities that were present in the influent plus any further solids added as part of the treatment process. Due to the dilute, active, and unstable nature of raw sludge, various conditioning, dewatering, and stabilization processes must be undertaken to treat it before final disposition. Once treated, the sludge can be disposed of through landfilling, land application, ocean dumping or incineration. A detailed discussion of these various final disposal options is presented in this section, including a description of the major sludge processing trains associated with each final disposal option.

Both land-based sludge disposal practices and sludge incineration represent disposal options which can be suitably adapted to a codisposal alternative, providng that economic and institutional constraints are not prohibitive. To examine the economic viability of codisposal as a sludge disposal alternative, cost estimates have been developed for each of the sludge disposal options. Specific information on the derivation of those estimates is presented in this section and in Appendix B.

At its origin in the treatment process, the sludge stream is highly liquid, typically containing less than 4 percent solids. Prior to disposal, this stream must be treated to increase the solids content and, in some cases, to stabilize its active biological and chemical constituents. A number of different sludge handling and treatment techniques, shown in Figure 1, are currently in use. In designing a sewage treatment process, the decision of which sludge handling train to use is influenced by a number of variables, including the nature of the sludge, estimated process costs, and regulatory requirements. Sludge processes are also limited by the locally available options for ultimate sludge disposal. For example, if only limited landfill area is available, then incineration may be the next most attractive option. Once decisions such as this have been made, the nature of the process used to prepare the sludge for disposal can be seen more clearly.

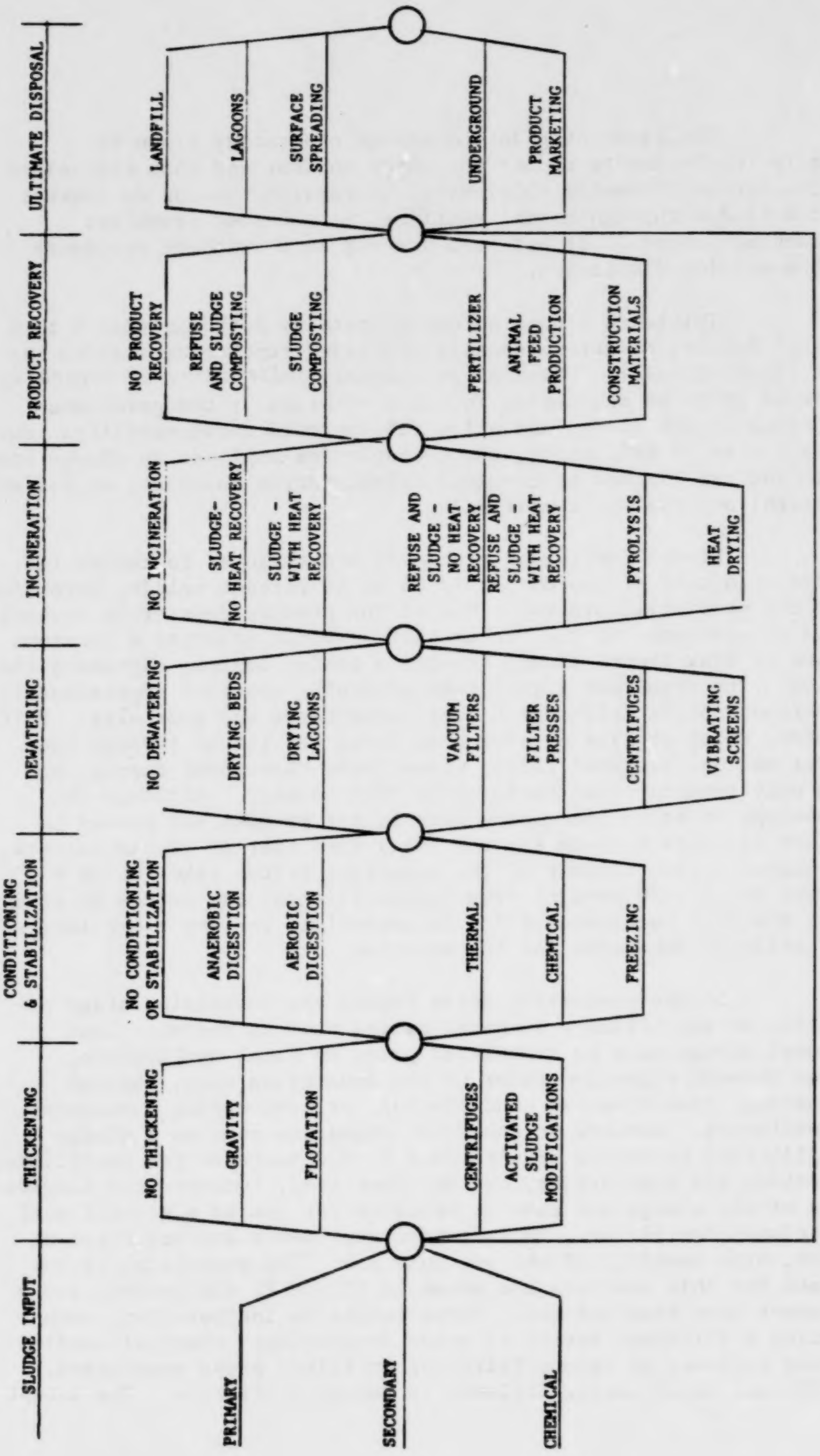
SLUDGE INPUT
PRIMARY
SECONDARY
CHEMICAL
THICKENING
NO THICKENING
GRAVITY
FLOTATION
CENTRIFUGES
ACTIVATED SLUDGE MODIFICATIONS
CONDITIONING & STABILIZATION
NO CONDITIONING OR STABILIZATION
ANAEROBIC DIGESTION
AEROBIC DIGESTION
THERMAL
CHEMICAL
FREEZING
DEWATERING
NO DEWATERING
DRYING BEDS
DRYING LAGOONS
VACUUM FILTERS
FILTER PRESSES
CENTRIFUGES
VIBRATING SCREENS
INCINERATION
NO INCINERATION
SLUDGE-NO HEAT RECOVERY
SLUDGE - WITH HEAT RECOVERY
REFUSE AND SLUDGE - NO HEAT RECOVERY
REFUSE AND SLUDGE - WITH HEAT RECOVERY
PYROLYSIS
HEAT DRYING
PRODUCT RECOVERY
NO PRODUCT RECOVERY
REFUSE AND SLUDGE COMPOSTING
SLUDGE COMPOSTING
FERTILIZER
ANIMAL FEED PRODUCTION
CONSTRUCTION MATERIALS
ULTIMATE DISPOSAL
LANDFILL
LAGOONS
SURFACE SPREADING
UNDERGROUND
PRODUCT MARKETING
TRANSPORTATION MECHANISMS (PIPE, RAIL, TRUCK, BARGE)

Figure 1. Alternative sludge processing systems. Source: Stanley Consultants, sludge processing and disposal, (2).

The first step in the sludge processing train is usually thickening to reduce the water content and thus the volume of the sludge. Gravity thickening, increasing the solids content of the sludge through normal settling, is the most prevalent thickening process. It has been assumed as a standard procedure in the ensuing discussion.

Thickened sludge normally contains approximately 4 to 6 percent solids, therefore usually requiring further dewatering before final disposal. Chemical or thermal conditioning is typically employed prior to dewatering in order to break up the gelatinous structure of the sludge and allow for improved dewaterability. For the purposes of this study, the technologies employed in sludge conditioning are limited to chemical (alum, ferric chloride, or polymer addition) and thermal conditioning.

Sludge dewatering processes are employed to reduce the sludge to a cake of approximately 15 to 40 percent solids, depending upon the particular process. One of the primary dewatering technologies in use today is the vacuum filter, which utilizes a pressure vacuum to draw liquid sludge through a filter medium, capturing the solids. The resultant filter cake generally contains approximately 20 percent solids (although higher percentages are possible). Filter presses, which utilize pressures to force the liquid through the filter medium, are used fairly extensively throughout Europe, but have only recently been employed in this country. Although the technology of batch processing with filter presses has proved to be less reliable to date (in the U.S.) than that of vacuum filters, the higher solids content of the resulting filter cake (up to 40 percent vs. the 20 percent from vacuum filters) can reduce or eliminate the fuel requirements for incineration, thereby establishing a significant incentive for its adoption.

Sludge processing steps beyond the dewatering stage are specific to the ultimate disposal option that is chosen. Land disposal sludge must be stabilized prior to final application, either through digestion prior to the dewatering step, through composting, lime/chemical conditioning, or heat-drying subsequent to dewatering. Aerobic or anaerobic digestion used as a sludge stabilitizing technique results in a sludge suitable for landfilling. Composting and heat-drying, on the other hand, conserve the nutritive value of the sludge and make it suitable for use as a general soil conditioner/fertilizer. Incineration represents another disposal option, with landfill of the residual ash. The processing trains defined for this analysis are shown in Figure 2. Altogether, seven processes have been defined. Three relate to incineration, each assuming a different method of prior dewatering: chemical conditioning followed by vacuum filtering or filter press dewatering, and thermal conditioning followed by vacuum filtration. The intent of these differences is to illustrate the trade-off among dewatering processes to achieve differing solids levels prior to incineration. Also, each incineration process distinguishes between multiple hearth and fluidized bed incineration. The remaining four process trains relate to anerobic vs. aerobic digestion prior to landfilling, or landspreading and flash drying vs. composting prior to distribution. An assumption has been maintained throughout this discussion that the sludge would be 60 percent primary and 40 percent waste-activated, with a volatile solids content of not less than 70 percent. It is further assumed that the solids ratio of the influent approximates 870 dry lb. per one million gallons per day.

Landfilling/Land Disposal. As Table 5 illustrates, approximately 50 percent of the nation's sludge is disposed of through land application, either through the landfilling/landspreading of liquid or dewatered sludge, or through composting/heat drying of the sludge with distribution for crop use.

Landilling accounts for approximately 25 percent of the total sludge produced in the U.S. It involves the truck delivery of stabilized, dewatered sludge to a sanitary landfill where the sludge is spread and compacted. At the end of each day's work the sludge is covered with a layer of soil. As the landfill is completed, a deeper layer of earth is compacted over the fill and planted to control erosion. If it is of good quality, dried sludge can be mixed with the final cover to condition the soil. The methods for the sanitary ladnfilling of sludge are well developed, as it has served as one of the most prevalent methods of disposal for many years.

The major cost elements associated with sludge landfilling derive from the transportation of the sludge to the landfill site, land purchase or lease, and the operation and maintenance of the landfill. In general, landiflling is a relatively inexpensive method of sludge disposal, where suitable land is available within reasonable hauling distances. We have estimated that landfilled sludge currently costs $75.00 to $160.00 per dry ton for disposal, including dewatering.

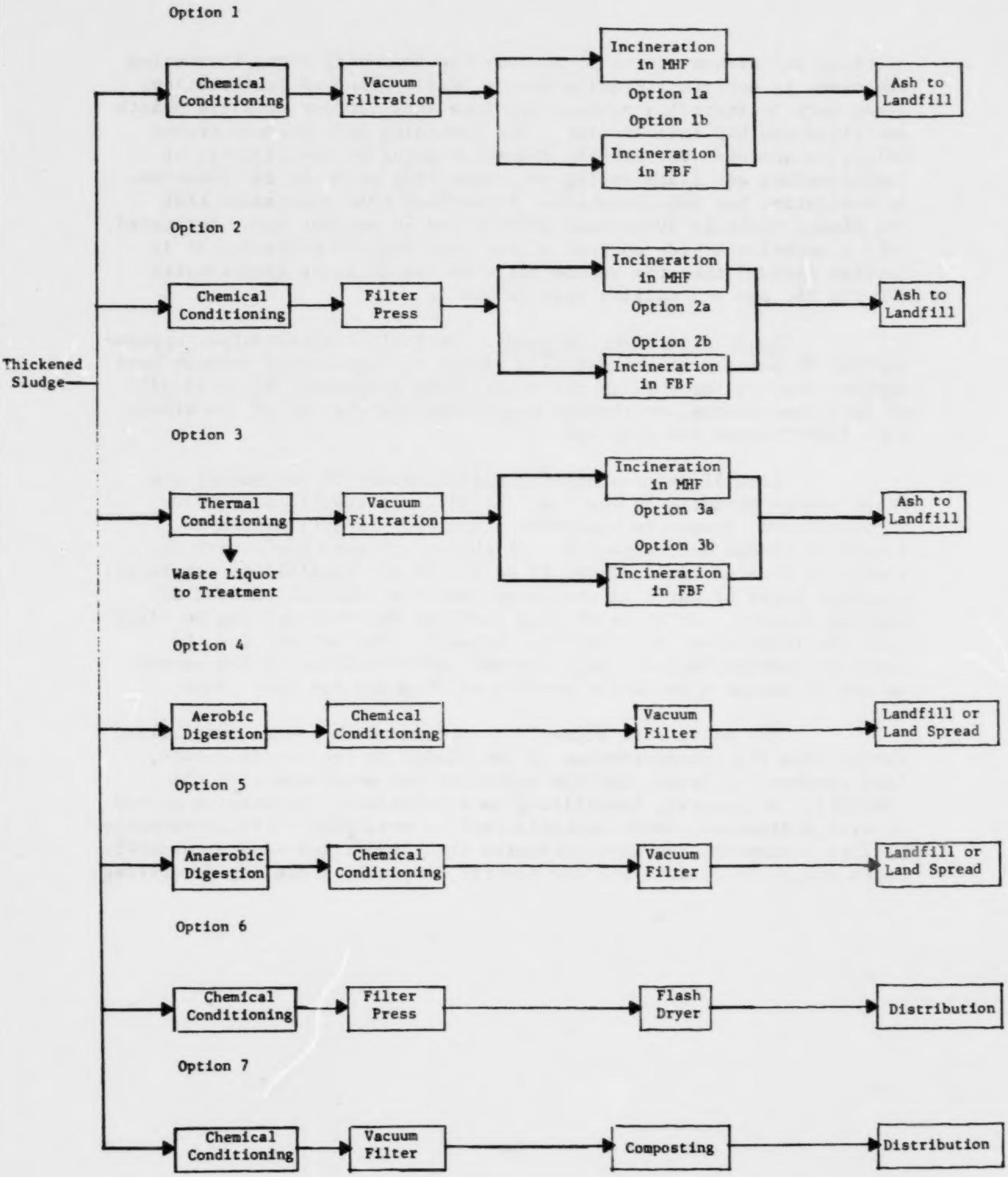
Option 1
Thickened Sludge
Chemical Conditioning
Vacuum Filtration
Incineration in MHF
Option 1a
Option 1b
Incineration in FBF
Ash to Landfill
Option 2
Chemical Conditioning
Filter Press
Incineration in MHF
Option 2a
Option 2b
Incineration in FBF
Ash to Landfill
Option 3
Thermal Conditioning
Waste Liquor to Treatment
Vacuum Filtration
Incineration in MHF
Option 3a
Option 3b
Incineration in FBF
Ash to Landfill
Option 4
Aerobic Digestion
Chemical Conditioning
Vacuum Filter
Landfill or Land Spread
Option 5
Anaerobic Digestion
Chemical Conditioning
Vacuum Filter
Landfill or Land Spread
Option 6
Chemical Conditioning
Filter Press
Flash Dryer
Distribution
Option 7
Chemical Conditioning
Vacuum Filter
Composting
Distribution

Figure 2. Representative sludge processing trains.

TABLE 5

ESTIMATED CURRENT DISPOSITION OF SLUDGE*

Disposal Method	% Total Sludge
Landfilling	25
Land Application:	
Croplands	20
Others	5
Incineration	35
Ocean Dumping	15

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*Source: 1974 Needs Survey, 1968 Inventory, Construction Grants Files.

Land Application. Another low-cost, land-based disposal alternative which is gaining increasing popularity is sludge composting.* Composting is a method of biological oxidation of the organic matter in sludge by thermophilic organisms. Under good conditions, Composting can dewater the sludge and destroy its odorous components, destroy or reduce the disease-producing organisms in the sludge because of the elevated temperature. and produce an aesthetically acceptable and useful organic product.

In the composting process, dewatered sludge (typically at 20 percent solids) is delivered to the site and is usually mixed with a bulking agent. The bulking agent increased the porosity of the sludge to ensure aerobic conditions during composting. If the composting material is too dense or wet, it may become anaerobic, thus producing odors. If it is too porous, the temperature of the material will remain low, delay the completion of the composting, and reduce the killing of disease organisms.

Various bulking materials can be used; suitable low cost materials include wood chips, bark chips, rice hulls, and RDF-type portion of processed solid waste. Unscreened finished compost has also been used. Generally, one part sludge (20 percent solids) is mixed with three parts bulking agent, although this mixture can be varied depending on the moisture content of sludge, type of bulking agent, and local conditions.

Following composting, the product is removed and cured in storage piles for 30 days or longer. This curing provides for further stabilization and pathogen destruction. Prior to or following curing, the compost may be screened to remove a portion of the bulking agent for reuse or for applications requiring a finer product. The compost can also be used without screening. Removal of the bulking agent reduces the dilution of the nutrient value of the compost. The compost is then ready for distribution.

As with landfilling, the major costs associated with sludge composting relat to its dewatering, transportation to the composting site, land purchase or lease, and operation and maintenance costs for the composting operation. In addition, marketing and distribution may be incurred by a municipality which chooses to sell its sludge. However, it is becoming a common practice for municipalities to give away composted sludge free of charge in order to avoid these marketing costs. In so doing, the municipalities forgo the potential revenues from the sludge. Generally, however, marketing costs are likely to exceed the potential revenues, due to the low market value of soil conditioning materials. We have developed a current cost estimate for sludge composting of $80.00 to $130.00 per dry ton, including dewatering. This assumes free distribution and no revenue from the sale of the compost.

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*In this section of the report, only the static-pile or "Beltsville" method of composting is discussed. Other approaches involving mechanical digestors are also available but have not yet been widely used in this country.

A final land based disposal option which has been implemented by only a few municipalities in this country is the heat drying (flash drying) of sludge. Flash drying is the instantaneous removal of moisture from solids by introducing them into a hot gas stream. The process was first introduced in Chicago in 1932. Today, Milwaukee, Houston, and Largo, Florida, in addition to Chicago, heat some portion of their sludges.

Heat dried sludge generally results in a dry product (approximately 2 to 5 percent moisture) with some nitrogen content (generally around 5 percent) and other nutritive elements. High quality heat dried sludge can be used alone as a low analysis fertilizer; lower quality sludges are generally sold as a bulking agent for use in the production of synthetic fertilizers. Unlike composted sludge, heat dried sludge may command a market price in excess of the costs associated with its marketing and distribution depending upon the nitrogen content of the sludge and the transportation costs for moving it to market.

Heat drying is an expensive sludge disposal option because of fuel costs (unlike incineration, no heat value is recovered from the sludge). It is also a highly capital-intensive process in comparison with alternative land disposal options. Many flash drying installations have been abandoned due to high costs, odor problems, and air pollution and explosion problems associated with the fine particulates.* In addition, the market acceptance of heat dried sludge appears to be declining, thereby reducing the likelihood of obtaining revenues from its sale. Gordian has estimated the cost of sludge disposal through heat drying to be approximately $124 to $180 per ton, including a $20 per ton credit from sales revenues.

The outlook for the continued disposal of sewage sludge through land application appears to be questionable at this time, due to anticipated regulatory changes. The Resource Conservation and Recovery Act of 1976 requires that regulations be established for the land disposal of sludge, including disposal by landfill. These regulations, which are still in draft form, will restrict the conditions under which sludge can be applied to the land, depending upon such factors as soil pH, the heavy metals content of the sludge, and the use of the land (e.g., agricultural or non-agricultural, food chain or non-food chain, etc.). The proposed regulations are expected soon.

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*Culp/Wesner/Culp, Municipal wastewater sludge management alternatives.

In addition to federal regulatory requirements, 35 states now impose requirements on the land disposal of sludge, or have at least promulgated a policy regarding land disposal. These regulatory and policy controls range from ad hoc evaluation of individual proposals to strict requirements for dewatering and stabilizing sludges prior to land disposal. In some cases, the effect of these regulations and requirments is to increase the cost of land disposal or to introduce significant obstacles into the planning process.

Incineration. Incineration is used to dispose of approximately 35 percent of the nation's sludge. In essence, incineration is a method that divides ultimate sludge disposal between two receiving media. The oxidized organics (mostly as H_2O and CO) are disposed of as gases into the atmosphere, while ash and particulates from flue gases are collected and deposited in a landfill with considerable reduction in the mass and volume of solids. Incineration is the most widely used single method of sludge disposal (see Table 5). It is expected to increase in prevalence in the future, reflecting both a growing interest in the recovery of heat value from sludge and an anticipated trend away from landfilling.

Because of the relatively high moisture content of sludge, incineration involves both drying and combustion. Drying is partially accomplished by dewatering prior to incineration, but even after mechanical dewatering, the sludge feed to incinerators typically contains some 60 percent to 80 percent moisture. Before solids combustion can be complete, this moisture must be evaported. With a sludge feed of less than about 25 percent solids (assuming not less than 60 to 65 percent volatile solids), some additional fuel is required to sustain combustion in incinerators of contemporary design. As the solids content and/or volatility increases, the requirement for additional fuel decreases to the minimum required for start-up purposes. It is important to ensure that adequate time is allowed in the combustion cycle for moistue to be evaporated and that a certain amount of turbulence be designed into the movement of the sludge through the combustion unit to assist heat transfer to the moist incoming feed.

Incineration also carries with it the possibility of air pollution from stack gases. There is concern regarding the emissions of odors; particulates; HCl, CO, SO_2, and NO_x; toxic metals; and organic compounds. In investigations of incinerator emissions, EPA has concluded* that properly designed and operated incinerators can achieve all presently applicable particulate emissions standards.

In general, sludge incineration is the most expensive form of sludge disposal. It requires a highly capital-intensive process train, and can also entail significant fuel costs. Specific fuel requirements are largely a function of the water and inerts content of the sludge; incineration of a 20 percent solids filter cake requires 6 to 10 MBtu per dry ton, whereas sludge with a 35 percent solids content is essentially autogenous (depending on solids composition and condition). It would appear that dewatering to 35 percent solids is desirable, however, the costs of further dewatering the sludge to this degree may exceed the resultant fuel savings, depending upon the scale of the plant and the particular technology that is employed. We have estimated that the total disposal costs for incinerated sludge at 20 percent solids are $130 to $230 per dry ton. A range of $110 to $240 per dry ton is estimated for a 35 percent filter cake.

Ocean Disposal. For seaborad communities on both the East and West Coasts of the U.S., the ocean dumping of sewage sludge and other waste products (demolition debris, refuse, dredge spoils, etc.) has been an economically attractive and operationally simple disposal alternative. It involves only the collection and barge transport of liquid sludge to a designated point at sea where the sludge load is discharged.

In recent years attention has been focused on the hazards that this procedure poses to marine life, as well as the aesthetic problems that can be created as sludge migrates toward the shoreline with ocean current. Consequently, an EPA ban has been placed on any further ocean dumping, with all current ocean dumping to be ceased by 1981. Thus, the 15 percent of the nation's sludge which is currently ocean dumped will either be applied to land or incinerated in the future.

2.2.2 Summary of Sludge Disposal Costs. Table 6 represents a summary of the cost estimates for the various sludge disposal alternatives, with schematic diagrams of the alternative sludge process trains shown in Figure 2. The specific methodology used in calculating costs, as well as a detailed presentation of costs for each

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*U.S. EPA, Process design manual for sludge treatment and disposal.

TABLE 6

SUMMARY OF SLUDGE DISPOSAL COSTS*†

Disposal Alternatives ‡	Capital Costs ($ x 10^3)			Annual Operating Costs ($ x 10^3)			Total Cost ($/Ton)			Revenue Potential ($/Ton)	Net Cost ($/Ton)		
	10 TPD	50 TPD	100 TPD	10 TPD	50 TPD	100 TPD	10 TPD	50 TPD	100 TPD		10 TPD	50 TPD	100 TPD
OPTION 1:													
(a)§	3,250	10,000	18,500	730	2,781	5,118	200	153	140	-	200	153	140
(b)	5,105	11,050	16,350	839	2,821	4,765	230	155	131	-	230	155	131
OPTION 2:													
(a)	4,500	11,800	19,500	747	2,412	4,295	205	132	117	-	205	132	117
(b)	6,355	12,850	17,350	876	2,556	4,151	240	140	113	-	240	140	113
OPTION 3:													
(a)	4,500	13,200	24,500	836	2,688	4,995	230	148	137	-	230	148	137
(b)	6,355	14,250	22,350	1,045	3,232	5,451	265	156	133	-	265	156	133
OPTION 4:	2,019	6,570	12,700	586	2,001	3,713	161	113	101	-	161	113	101
OPTION 5:	2,020	6,370	11,600	485	1,673	2,794	133	92	76	-	133	92	76
OPTION 6:	3,066	9,666	16,633	716	2,834	5,198	198	156	144	20	178	136	124
OPTION 7:	1,210	4,500	9,200	460	1,705	2,978	126	94	81	-	126	94	81

* Source: Gordian Associates Inc.
† All values are stated as 1978 dollars per dry ton of solids.
‡ Refer to Figure 2 for description of disposal options.
§ (a) refers to incineration in MHF while (b) refers to incineration in FBF.

unit process, are included in Appendix B. These estimates are not intended to indicate the actual costs that might be incurred by a specific project; rather, they were developed as a general reflection of the current costs of hypothetical sludge processing trains. Together with similar cost estimates for solid waste management processes, these can be used for determining the kinds of solid waste/sludge management options within which codisposal might be economically preferable to sole-purpose facilities.

The primary source document for the cost estimates employed here is a recent study of sludge disposal options in Nassau County, New York.* This report was selected as a reference document for several reasons:

- The numerous reference documents dealing with sludge disposal costs present a set of estimates that is too disparate to be useful for comparisons. Further, the disparities in these documents are not always evident in explicit assumptions, making it impossible to adjust the data to standard assumptions.
- The Nassau County report is based on general cost functions developed previously for EPA. These cost functions appear to underly a number of other sources of cost data; the curves represent as widely used a data source as any reviewed in connection with this study.
- The Nassau County report presents data that have been adjusted to reflect recent (1977) cost levels on the East Coast. These would seem to be representative of the higher costs expected in urban areas where density and population levels might make codisposal a potential alternative.

The estimates developed from this single source were compared with other references. In most cases, there was general agreement. However, a specific adjustment was made to address apparent inconsistencies, for example, the fuel costs of sludge incineration for solids contents of 18 to 20 percent (typical of vacuum filtered sludge). The adjustments were developed using various sources, including the EPA Process Design Manual and the Culp/Wesner/Culp report.** In making these adjustments, it appears that the inconsistency in fuel usage originates with such basic sources as the EPA cost curve,* for it was noted in a number of the sources that used these curves.

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*Consoer, Townsend & Associates, Nassau County, N.Y. sludge management study.

**U.S. EPA, op. cit.; Culp/Wesner/Culp, op. cit.

Another point of interest is that EPA's recent studies of historical construction cost data for sewage treatment plants indicate that for most sludge handling unit processes, there are diseconomies of scale. This contradicts the economies of scale shown in Table 6. However, it is felt that the diseconomies noted in EPA's analysis are idiosyncracies of the statistical analysis, rather than significant findings from the data sample.

2.3 Codisposal Processes

The primary purpose of this discussion is to provide an overview of the currently practiced methods of disposing of municipal solid waste (MSW) and municipal sewage sludge (MSS) simultaneously, in the same place and/or manner. The emphasis is on understanding how the two waste streams combine, and on identifying what the union means in terms of process steps or costs that can be eliminated or in terms of new technology required. In this section, the most viable codisposal processes are described. The following section addresses costs and other economic considerations.

One of the fundamental assumptions used here is that the sewage sludge is of a standard nature. Sludge can vary widely in chemical composition and its percentage of volatiles, depending on influent characteristics and on the means of treatment. For the purposes of this report, it is assumed that the sludge derives from general residential sources (as opposed to specialized industries) and that it is a mixture of primary and waste activated sludge with 70 percnet volatile solids. Similarly, the solid waste is assumed to represent the generally accepted average characteristics of 5000 Btus per lb., 150/yd^3 density, and 75 percent combustible (weight) with 20 percent moisture as received.

Further assumptions must be made concerning the transporting distances for MSW and MSS in order to develop generalized systems for comparison. Except for solid waste landfilling, if the codisposal process is primarily for MSW disposal, the sludge is assumed to be pumped in a pipeline at 4 to 6 percent solids to the site. For a landfill, the sludge may well be trucked to the site. If the process is basically for sludge disposal, then any MSW processing facility is assumed to be co-located. These assumptions are based on the premise that MSW must be collected by a vehicle in any case and therefore it can be re-routed more easily.

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*U.S. EPA, Areawide assessment procedures manual, Appendix H.

A final important assumption concerns the ratios at which MSW and MSS quantities will realistically combine. The viable set of ratios will determine how the two waste streams, with their respective territorial boundaries and component populations, can fit together, if at all. One point to consider is the ratio of the solid waste and sludge generated from equivalent populations. Generally accepted daily generation rates of 2.5 dry lbs. of MSW (3.3 lbs., as received) and 0.2 lbs. of dry sludge solids per capita are equivalent to a ratio of 13 parts of MSW to one part of MSS. This ratio is considered for each codisposal alternative presented in this study whenever it proves feasible. However, for several of the processes discussed, operating at the ratio is not realistic. Further, it is often impractical to consider wastes from equivalent populations because of political or institutional factors.* For these reasons, this study does not limit the discussion of MSW:MSS ratios to equivalent populations, but instead stresses the quantity constraints imposed by the technology of the codisposal processes themselves. As a result, each of the systems examined in the following section will be discussed in terms of its own optimal ratio as well as the ratio of equivalent populations for reference. A summary of the refuse to sludge ratios is presented in Figure 3.

2.3.1 Codisposal in a Sanitary Landfill. Figure 4 presents a generalized flow chart for codisposing MSS and MSW in a sanitary landfill. The techniques employed depend upon the nature of the sludge. If thickened (four to eight percent solids) sludge is used, it may be piped or trucked to the landfill site and sprayed onto a layer of solid waste. This mixture is then covered with a layer of soil. The procedure is the same for dewatered sludge (20 percent solids) except that it will have been transported by truck and spread by machine. Both approaches require that the sludge be stablized by digestion as a first step in handling. The most important difference between the two sludge landfilling methods is in the ratio of sludge to solid waste, based on the absorptive capacity of the refuse. The results of the Oceanside, California** demonstration project indicate that one pound of solid waste can absorb 0.4 to 2.1 lbs. of sludge (5 percent solids). However, the report concludes that in order to provide a margin of safety against leachate

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*See Chapter 3 for a detailed discussion of this matter

**Stone, Disposal of sewage sludge into a sanitary landfill.

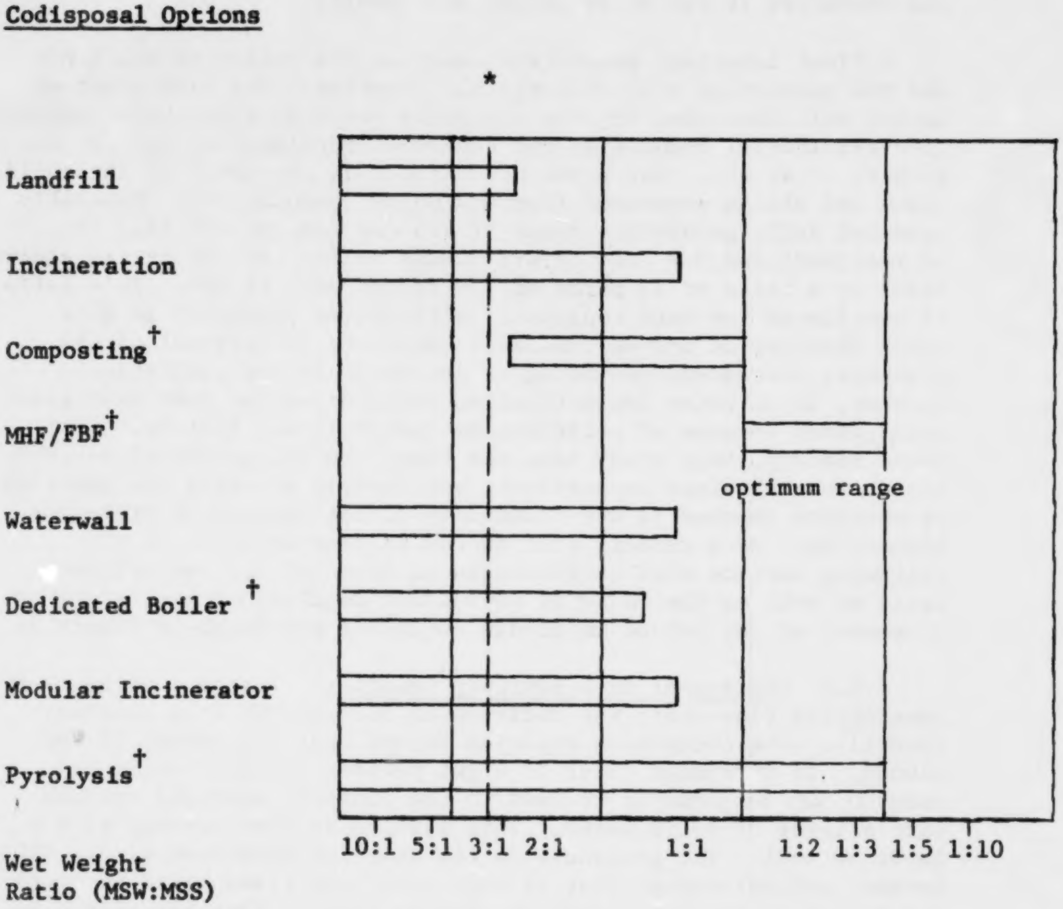

Figure 3. Refuse to sludge ratios for major codisposal options.

* Vertical dashed line represents combined waste stream (MSS & MSW) generated by equivalent populations (13:1 dry weight ratio of MSW to MSS) using 20% solids MSS.

† Note that these codisposal options employ RDF instead of raw MSW. RDF is 75% (by weight) of incoming MSW. The scales and ratios shown here are all for raw MSW plus MSS only.

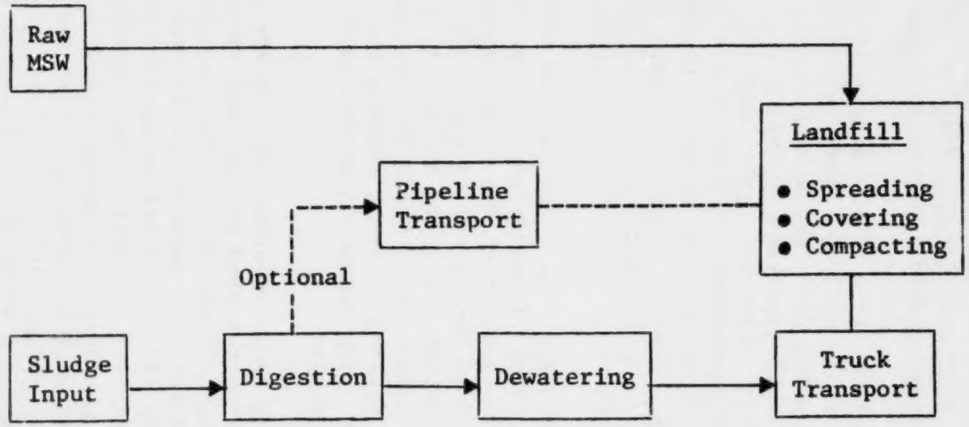
Raw
MSW
Landfill
• Spreading
• Covering
• Compacting
Pipeline
Transport
Optional
Sludge
Input
Digestion
Dewatering
Truck
Transport

Figure 4. Landfill codisposal.

problems, a ratio of 40 lbs. of MSW to 1 lb. of sludge (dry weight) is desirable for sludge at 5 percent solids. If dewatered (20 percent solids) sludge is used, the safe ratio translates to 10 lbs. solid waste for every one lb. of sludge (dry weight). This safety margin is designed to accommodate natural precipitation, but in wet climates or following periods of heavy rainfall, application rates may have to be adjusted. If these rations are not exceeded, it appears that leachate problems arising specifically from the inclusion of sludge in a solid waste sanitary landfill may be avoided.

The dry weight ratio of MSW generation to MSS generation for equivalent populations is 13:1. Therefore,it can be seen that liquid sludge will combine with refuse at a ratio that implies either a larger MSW population base or only a partial solution to sludge disposal. These conditions might describe the situation where a regional landfill accommodates the solid waste disposal needs of a large geographical area, but only a small, centralized population is served by a sewage treatment plant. It might also apply in cases where industrial sludge is the potential candidate for codisposal, provided that the sludge does not contain hazardous waste products.

Dewatering the sludge to 20 percent soldis will increase the ratio beyond the point of equivalent populations, so that a larger sludge producing population can be accommodated. At this level, the landfill could handle all of the sludge from the solid waste generating population with some additional safety margin. This additional flexibility would apply in situations where more than one landfill is serving an area, raising the possibility that just the site closest to any waste water treatment plant could handle all of its dewatered sludge.

Landfilling as a codisposal option has several potential benefits. It eliminates the need for any additional sites or facilities for separate sludge disposal. It has been reported that the increased moisture in the fill reduces vector problems and aids in the control of blowing litter. Where undigested and/or primary sludge is used, it may also increase methane generation, thereby improving the site's potential for energy recovery. If the sludge spreading operation is well designed, there should not be any appreciable rise in the operating costs of the landfill. For those communities that are not facing a shortage of permitted landfill space and where hauling costs are not prohibitive, this may well be the most attractive codisposal option.

Any of the landfilling codisposal options will be significantly affected by the RCRA guidelines being drafted by EPA. The preliminary signals from EPA indicate that most sewage sludge will be regarded as non-hazardous waste which will be subject to the recently published RCRA section 4004 landfill criteria rather than the RCRA subtitle C, hazardous wastes regulations. Final Federal regulations are expected in early 1980.

2.3.2 Codisposal in Coventional MSW Incinerators. Conventional, refractory walled solid waste incinerators without heat recovery exist in many major cities as a means of reducing the volume of the MSW that must be landfilled. For such cities, the coincineration of MSS with refuse could be a codisposal option. The process describes here is a generalized, theoretical approach drawing upon engineering principles discussed in Weston's report and elsewhere.* This discussion is intended merely to provide a preliminary knowledge of the more important principles involved in the coincineration of refuse and sludge. Past experimentation with coincineration has led to the conclusion that sludge must be partially dried in order to achieve successful combustion. The sludge is dewatered to 20 percent solids and then fed into a direct drier heated by hot flue gases from the MSW incinerator. The dried sludge is blown into the incinerator's combustion chamber along with exhaust gases from the drier. Before the moist exhaust gases from the drier are released to the atmosphere, they are heated to 1400°F to destroy odors. Residues are removed as usual and landfilled.

This coincineration process is shown in Figure 5. The most important variables in the system are the nature of the sludge (percent volatiles versus ash) and the type of drier utilized. The volatility of the sludge determines its Btu content as well as the quantity of ash left as residue after combustion. The heat transfer efficiency of the drier is also critical in determining the possible ratio of MSW to MSS.

There are severable notable exceptions to this process. The coincineration facility in Norwalk, Connecticut and a planned facility for Glen Cove, New York, employ different drying techniques. In their approach, dewatered sludge (20 percent solids) is sprayed onto the MSW as it feeds into the combustion grate. The residence period during combustion is designed to be of sufficnet length to evaporate the moisture to the point where the sludge will combust.

An essential consideration with any of the approaches to coincineration is the requirement for heating the moisture-laden drier

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*An excellent discussion of the thermodynamics of combined sludge and refuse incineration is provided in Klaus Feindler's paper on the Krefeld, Germany codisposal plant. This paper is included as Appendix D to this report.

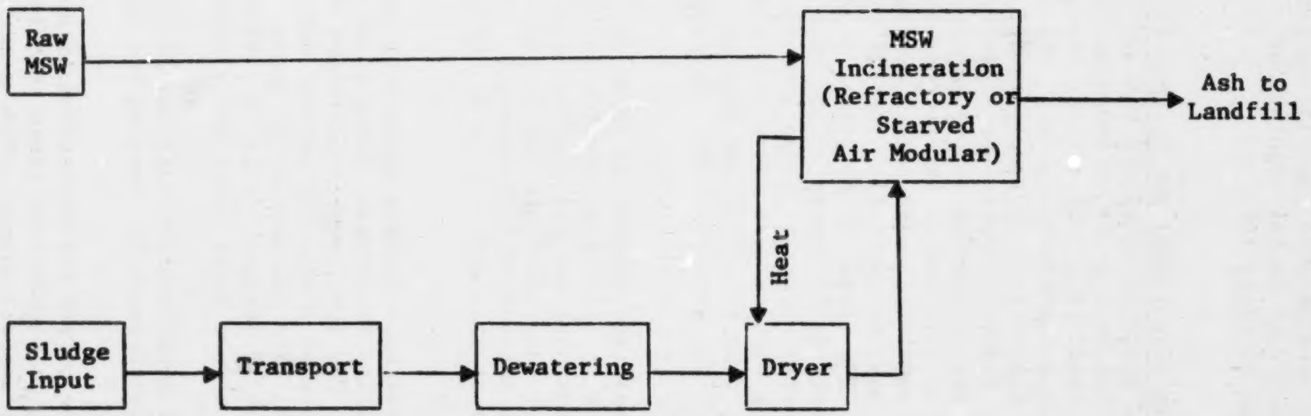
Raw MSW
MSW Incineration (Refractory or Starved Air Modular)
Ash to Landfill
Heat
Sludge Input
Transport
Dewatering
Dryer

Figure 5. Coincineration of MSS with solid waste (no energy recovery).

exhaust gases to the point where odor causing organics are destroyed. A temperature of 1400°F is necessary to accomplish this. Thus, the entire coincineration process must generate enough energy to dry the sludge, sustain thorough combustion of refuse and sludge, and raise the furnace exit gas temperature to 1400°F. According to the 1976 Weston Engineering study, the key to maintain this energy balance is the moisture content of the input mix of MSS and MSW. The results of that study indicate that for typical refractory lined incinerators, a total (MSW plus MSS) input moisture content of not more than 50 percent must be maintained.

With this requirement, the refuse to sludge ratio for typical MSW (80 percent solids) and vacuum filtered (20 percent solids) MSS ranges from a minimum of four parts solid waste to one part sludge (on a dry weight basis) up to any higher proportion of MSW. The equivalent population ratio of 13:1 (MSW to MSS) is well within this range, even when a reasonable allowance for variation in refuse moisture content is included. The basic ratio (4:1) allows for a larger sludge generating population than MSW base, which is well suited to the idea of multiple incinerator sites with the one closest to the sewage treatment plant able to accommodate all of the sludge.

There are several potential considerations related to the widespread implementation of coincineration. One is the possibility of air pollution emission problems. Sludge incineration will contribute additional trace metals or particulate pollutants. A related difficulty is that the inert components of the sludge may become concentrated in the ash. If trace metals are present in the sludge ash, the concentrations may become high enough to cause the residue to be classified as a hazardous waste, with concomitant problems in landfilling of the final residues. These are issues that would be examined and resolved on a case-by-case basis and consequently are not dealt with in this generalized process discussion.

2.3.3 Codisposal in a Sludge Composting Operation. Composting MSS to produce a stable soil conditioner is gaining popularity in communities considering alternative sludge disposal options. MSW alone has been tried in the past without much success in this country, although in Europe, there are numerous succesful plants. The combination of sludge and refuse in a composting operation can be considered a technically proven process which merits discussion.*

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*There are several continuing problems with composting such as fungus growth,but the process has been operational for some time in Altoona, Pennsylvania and in several European installations.

The basic composting system is shown in Figure 6. The MSS process is unchanged from the previously described, sludge-only composting approach, except that processed solid waste is added as a bulking agent instead of wood chips. The raw MSW must undergo considerable processing in order to produce a marketable composted product. Obviously, most non-organics should be removed from the solid waste stream. The representative system described here employs a full recovery front end processing train to separate ferrous metals, aluminum and glass; it would produce an RDF-like material for use in the composting system. The solid waste processing system is assumed to be co-located with the sludge composting operation. Dewatered sludge may be trucked to the site.

There are currently two main variations in the composting technique, both of which have proven feasible in the U.S. on a demonstration scale. One is the forced aeration static pile approach developed at the USDA Agricultural Research Center in Beltsville, Maryland. In this approach sludge and wood chips are mixed and spread in a pile over a pipe configuration which employs a blower to draw air through the pile, thus speeding digestion and eliminating the need for turning. The second approach utilizes a large enclosed mechanical digester to speed the stabilization process. The digester systems are also based on air being forced through the compost mixture, in this case through rotating auger-like arms which also help mix the sludge and bulking material. Mechanical systems are fairly widespread in Europe and a mechanical digester has been operating in Altoona, Pennsylvania for several years.

Both of these systems require that the mixture to be composted contain 40 to 60 percent moisture for optimal efficiency. For systems using wood chips and vacuum filtered sludge (20 percent solids), the recommended ratio is three parts bulking agent to one part sludge (by volume). If processed MSW is used (at 80 percent solids), it would combine at a 1:1 (MSW to MSS) wet ratio or a 4:1 ratio by dry weight. Since processed refuse represents about 75 percent of the weight of raw MSW, the maximum total ratio of MSW to MSS is 5.3:1. This blending ratio still falls short of the 13:1 mix produced by equivalent populations, indicating that composting can provide only a partial solution ot the solid waste disposal problem.

Tests have show that these composting methods are capable of accommodating raw sludge at 5 percent solids. In fact, at least one of the mechanical processes (Fairfield) claims to work best with that mixture. Results of experiments conducted at Beltsville, and with the Fairfield mechanical digester at Altonna, show that carefully designed compost systems are capabile of containing the odor and pathogen problems associated with undigested liquid sludge. Using

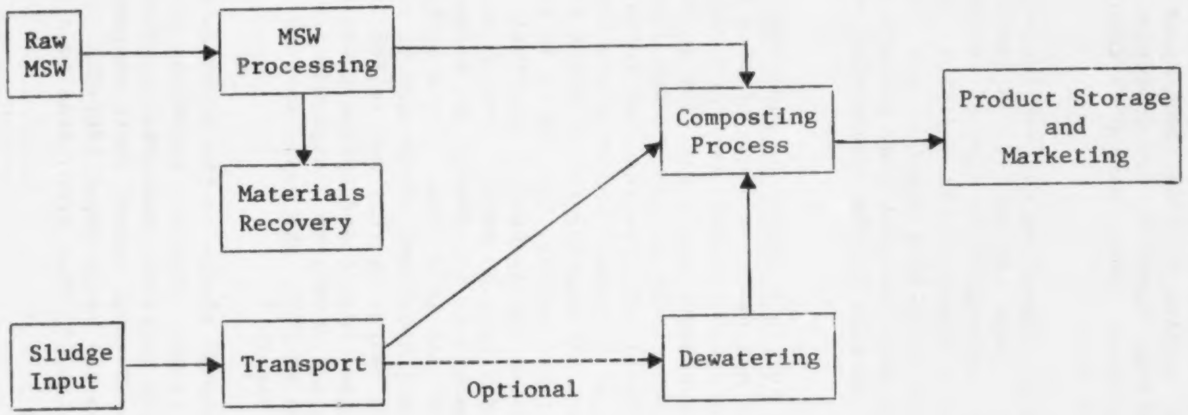
Raw MSW
MSW Processing
Materials Recovery
Composting Process
Product Storage and Marketing
Sludge Input
Transport
Optional
Dewatering

Figure 6. Codisposal through composting.

five percent solid sludge would tend to eliminate the cost of sludge dewatering, but it would also result in a substantial increase in the amount of bulking agent required. Since the cost of wood chips is increasing (Beltsville recently tripled), an approach employing a refuse derived bulking agent appears attractive. Contrary to expectations, however, the processed refuse is very costly in itself to produce. Cost trade offs result which are examined later in Section 2.4.

Codisposal through composting carries the same fundamental problem attendant to sludge composting: a questionable market for the end product, especially in view of pending EPA restrictions on the end use of sludges. In addition, the viability of processed refuse as a bulking agent is not clear. Researchers at the Beltsville facility feel that pelletized RDF may be more suitable, but this entails further processing and expense.

2.3.4 Codisposal in a Multiple Hearth or Fluidized Bed Sludge Incinerator. This approach has been the focus of much recent interest in codisposal with projects planned in Contra Costa County, California, and Memphis, Tennessee, and a facility in Duluth, Minnesota in final shakedown. For single purpose sludge disposal, multiple hearth furnaces (MHFs) and fluidized bed furnaces (FBFs) typically burn fossil fuel to evaporate the moisture from the dewatered sludge (20 to 40 percent solids) to the point of self-sustaining combustion. For codisposal, the system is essentially the same except that processed MSW is used as the fuel. For both types of furnace, the raw MSW must be passed through an RDF processing train, which can recover materials for resale and produces combustible shreds with a 3" to 6" particle size. For a multiple hearth furnace, processed refuse and dewatered sludge can be mixed prior to injection into the upper hearth or they may be fed in separately, with sludge entering the upper levels and refuse entering the middle hearths. Processed refuse and dewatered sludge may also be injected together or separately into an FBF. The basic systems of these two processes are depicted in Figure 7.

The use of thickened sludge as the input is theoretically possible for both furnace types. However, technical considerations, such as the huge hearth area required, make that approach impractical in many existing furnaces. Several recent tests suggest that optimum efficiency is obtained when the waste input (RDF+MSS) is a mixture that is 30 to 40 percent solids.* This translates to a dry weight,

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*A Review of Techniques for Incineration of Sewage Sludge with Solid Wastes, Roy F. Weston, Inc., December 1976 pp. 67-76 and personal communication with Terry Allen, Envir. Tech Engineering.

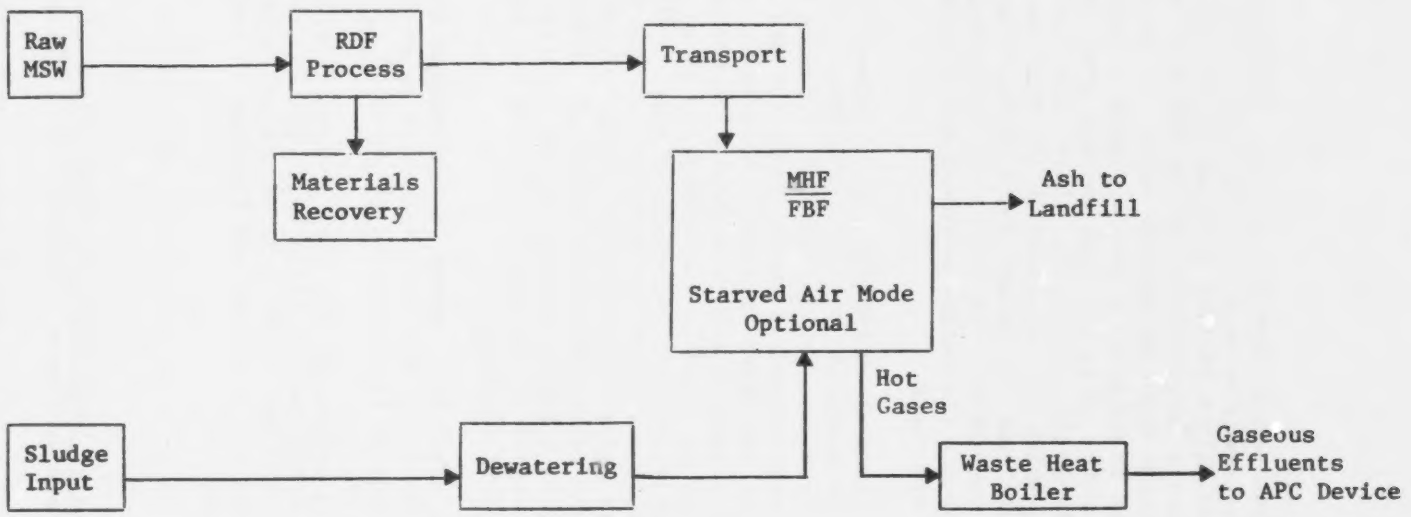
Raw MSW
RDF Process
Transport
Materials Recovery
MHF
FBF
Starved Air Mode Optional
Ash to Landfill
Hot Gases
Sludge Input
Dewatering
Waste Heat Boiler
Gaseous Effluents to APC Device

Figure 7. Multiple hearth or fluidized bed coincineration.

raw MSW to MSS ratio that ranges from 1:1 to 3:1. Since equivalent populations generate these wastes on a 13:1 dry basis, this codisposal option may provide only a partial solution to the solid waste disposal problem. Either a large portion of the RDF must be sold elsewhere, extra combustion capacity must be built, or the MSW processing facility must be built on a smaller scale to accomodate only a portion of the waste. With the high capital costs and distinct economies of scale in RDF processing, these three options present some tradeoffs, which are discussed in the next section. It is interesting to note that the Contra Costa facility includes extra capacity for RDF combustion. In Duluth the codisposal facility is not planned to handle the entire regional MSW flow until additional RDF markets are found.

There is an alternative approach to codisposal in an MHF, where the furnace is operated in a pyrolysis mode. The process is the same as combustion except that the incoming air is reduced to be below stoichiometric proportions; the gas resulting from pyrolysis of the mixed feed has a heat value of up to 130 Btu per sdcf. This pyrolytic gas is suitable for combustion in an afterburner and may be suitable for combustion in an existing boiler or furnace as a means of energy recovery. The MSW and MSS ratio is basically unchanged for this mode of operation, although slightly higher moisture percentages appear possible (up to 60 percent) as air requirements are reduced.* This approach has been tested briefly at a pilot facility at the Constra Costa project. The limited success of the initial testing has led to plans for a larger facility there.

It should be noted that, based on experiences in Europe and Contra Costa, EPA now feels that coincineration in an MHF under pyrolysis conditions is the preferred approach.**

Fluidized bed codisposal has been successfully demonstrated at the EPA supported demonstration hydra-pulping facility in Franklin, Ohio. The 400 TPD facility in Duluth which will codispose of RDF and MSS in two fluidized bed furnaces is now in the final shakedown phase.

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*Incineration-Pyrolysis of Waste Water Treatment Plant Sludges, R.B. Sieger and P.M. Maroney (Brown & Caldwell) U.S. EPA 1977.

**Sludge Treatment and Disposal; Sludge Disposal, (U.S. EPA Technology Transfer series), Vol. 2, EPA - 625/4-78/012, October 1978, pp. 23-24.

All of the MHF/FBF codisposal systems currently planned in the U.S. incorporate some form of energy recovery, usually through waste heat boilers which capture the heat contained in hot exit gases and transform it into steam.

It is also possible to retrofit existing multiple hearth and fluidized bed furnaces to accommodate RDF. The main modification required is adapting the feed system to accommodate RDF. The Contra Costa facility was retrofitted and the major MHF manufacturers feel that their furnaces can be easily adapted to codisposal.*

2.3.5 Codisposal in an MSW Waterwall Combustion Furnace. Widespread experience in Europe has shown that incineration of MSW and MSS in a mass burning waterwall furnace with heat recovery is a technically proven and even reliable method of codisposal.

The sludge handling approach employed in the European codisposal facilities encompasses a wide variety of technologies, ranging from indirect dryers using thickened sludge (4 percent solids as input - Dieppe, France) to direct dryers using dewatered sludge (25 percent solids - Lefeld , Germany).** The system which will be described here is a representative one, designed to illustrate general materials flow and some of the more important issues. It is not intended to represent the "best" or even most prevalent approach, since the merits of the alternative processes are still very much in debate.

A representative system, shown in Figure 8, is similar to the solid waste only combustion process discussed earlier. As a mass burning system, preprocessing of the MSW is not required. The sludge input, which can be pumped or trucked to the incinerator site as a liquid, is dewatered (20 percent solids) and fed into a steam-heated drier. (Note that it is also possible to use a direct drier employing hot fine gases.) When it has been dried to 85 percent solids, it is then fired in the combustion chamber.

The system designated for this analysis uses an indirect drier heated by steam as opposed to the direct drying method, where hot flue gases intermingle directly with the sludge.

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*Richards, D. and Gershman, H., The conversion of existing municipal sludge incinerators for codisposal.

**For a detailed explanation of European approahces see European Refuse Fired Energy Systems, Vol. 2, U.S. EPA, SW 176C.1, 1979

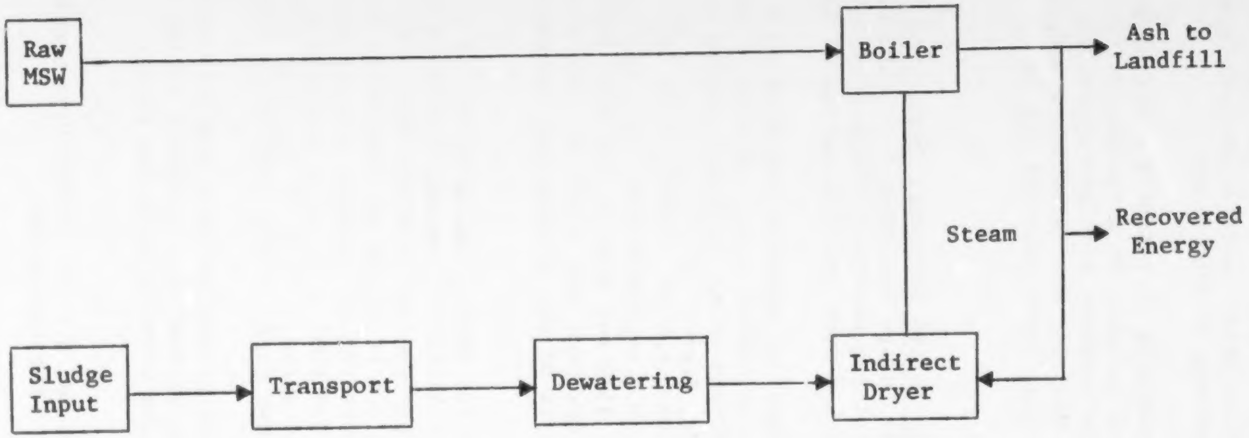
Raw MSW
Boiler
Ash to Landfill
Steam
Recovered Energy
Sludge Input
Transport
Dewatering
Indirect Dryer

Figure 8. Codisposal in a waterwall combustion furnace.

There are currently a number of different driers capable of handling this technique. Much of the technology has been developed in the food preparation industry. Among the driers currently in use are the jacketed or hollow-flight type, wiped-surface evaporators (widely used in Europe), and jacketed or steam-tube rotary driers. Some of the driers now in use recycle a portion of the previously dried sludge for use as an admixture to the incoming dewatered sludge, producing a 50 percent solids in-feed which exits the drier at about 85 percent solids. Drying thickened sludge (4 percent solids) is impractical for some drying approaches due to the energy demands of such a wet mixture and the potential for fouling of the drying surface, although, as noted earlier, the system at Dieppe operates using thickened sludge. Weston estimates that using 20 percent solids sludge as input to the codisposal system, at equivalent population input rates, some 15 percent of the boiler output will be consumed for sludge drying. The remaining steam (as well as steam generated by sludge combustion) is available as a potential source of revenue.

The ratio of refuse to sludge is likely to be limited in this case by practical and economic, rather than technical, considerations. For many systems, sludge drying is a net consumer of steam, even considering the steam regained when the dried sludge is burned. However, this is not always the case, the Krefeld system being a notable exception. Outside steam sales are a critical revenue source in the finances of waterwall combustion units,and the loss of saleable steam output through sludge drying will reduce the quantity available to supply outside demands. Even though the steam used for sludge drying would itself be sold, steam sales to the major users typically sought after for energy recovery projects involve large volumes of available steam. For those codisposal systems which involve reduction in the steam output of existing or planned MSW only facilities, pinning down markets in advance assumes even greater importance. For the purpose of this analysis, only ratios greater than ten parts of MSW to one part of sludge have been considered, in order to ensure that there would be sufficient steam output regardless of the sludge drying approach.

Despite the spread of waterwall combustion MSW incinerators in this country, only one system currently incorporates sludge disposal (Harrisburg, Pennsylvana). However, several other communities are considering this approach. The fact that codisposal waterwall applications are not further advanced in the U.S. is not the fault of technology but rather the consequence of institutional contraints.

2.3.6 Codisposal in an MSW Dedicated Boiler System. Dedicated boiler systems are gaining popularity as an MSW disposal option. Large new facilities are being constructed in Akron, Ohio and Niagara Falls, New York. While neither of these facilities currently plans to include sludge disposal, dedicated boilers should be compatible with codisposal in principle. The basic system, depicted in Figure 9, is fundamentally the same as the previously described waterwall system except that the incoming MSW is processed into RDF before entering the combustion chamber. The input sludge may be dried via direct or indirect drying, depending upon the ease of adaptability, thermodynamics, and economics of the specific system.

The most significant differences between this system and the waterwall system lie in the higher costs and increased revenue potential of the dedicated boiler, both of which relate to the higher energy transfer efficiencies of the semi-suspension combustion unit. With limited data it is not possible to comment definitely on such a codisposal system. Refuse to sludge dry weight ratios would not vary appreciably from those explained earlier for direct and indirect drying except that, since RDF instead of raw MSW is being added, the minimum proportion of refuse to sludge would increase.

2.3.7 Codisposal in an MSW Modular Incinerator. Thermal codisposal in a modular incinerator (as shown in Figure 10) differs from other incinerator-based systems only in scale. The process is essentially a solid waste mass burner with the capability for either direct sludge drying, or indirect drying when the system is equipped with a waste heat boiler. There are currently no codisposal modular incinerator facilities but, according to system vendors, the process is feasible. Coburning sludge and refuse is currently being tested at the Consumat Facility in North Little Rock and the unit under construction in Auburn, Maine includes plans for industrial sludge incineration.

One consideration for codisposal in modular incinerator systems is that the fairly low energy transfer efficiency of the combustion unit would affect refuse to sludge ratios. If energy recovery is involved, the amount of energy left over from sludge drying would also be less than for waterwall systems. MSW to MSS ratios could range upward from 3:1 (dry weight), although at that level there is not much allowance for the considerable moisture variability that occurs in the input refuse stream. Mixture at the generation ratio of equivalent populations (13:1) would be more desirable.

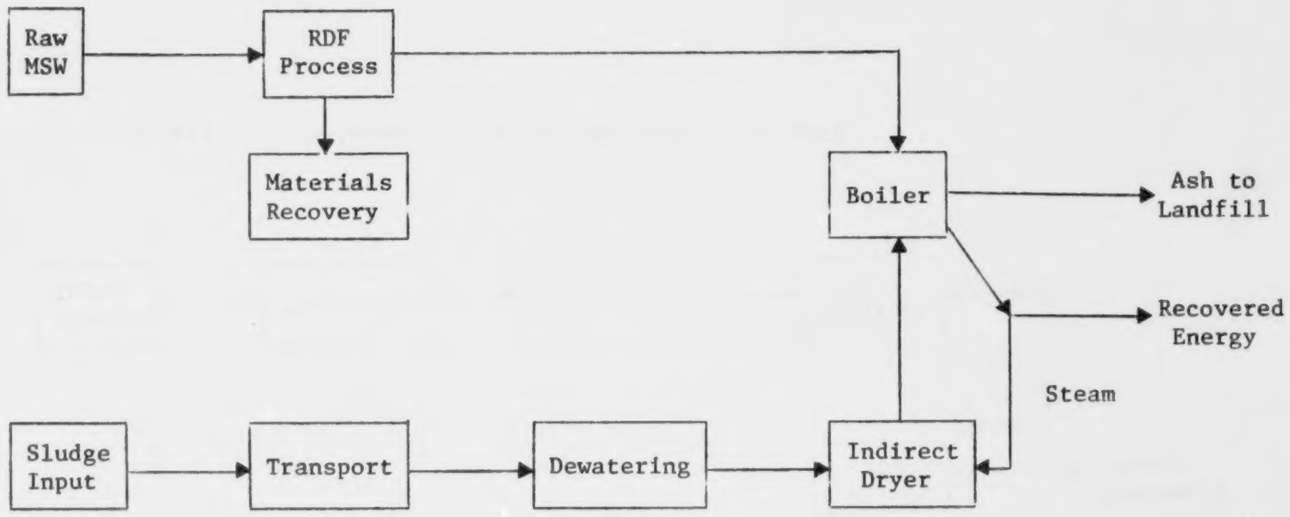
Raw MSW
RDF Process
Materials Recovery
Boiler
Ash to Landfill
Recovered Energy
Steam
Sludge Input
Transport
Dewatering
Indirect Dryer

Figure 9. Codisposal in a dedicated boiler system.

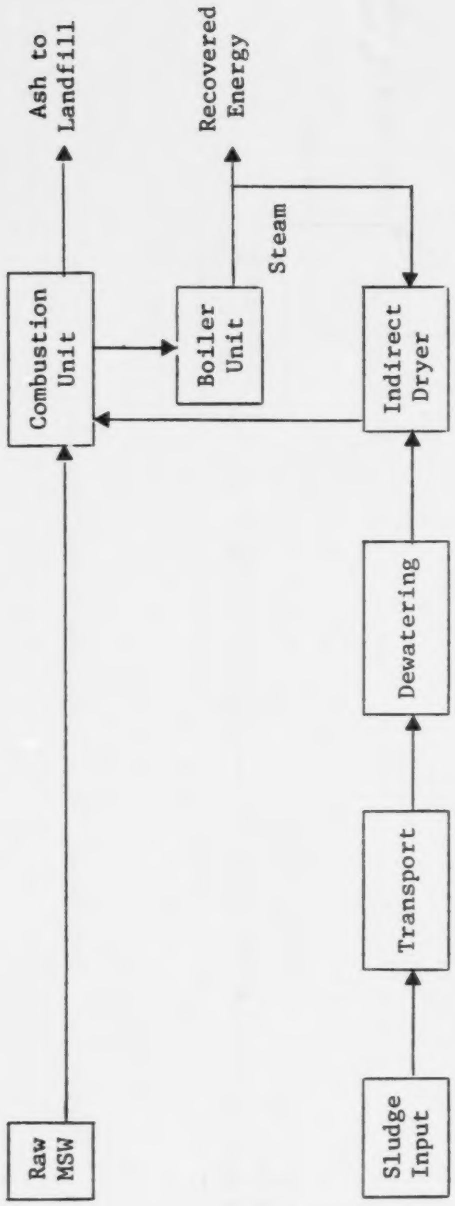
Raw MSW
Sludge Input
Transport
Dewatering
Indirect Dryer
Combustion Unit
Boiler Unit
Steam
Recovered Energy
Ash to Landfill

Figure 10. Codisposal in a modular combustion unit.

2.3.8 Codisposal in an MSW Pyrolysis System. Pyrolysis may be be used for the disposal of either MSW or MSS. The major sludge pyrolysis codisposal system has already been discussed in the multiple hearth furnace section. This section will discuss codisposal in developmental pyrolysis systems that are primarily for the disposal of MSW. The generalized system is presented in Figure 11. This system assumes a representative pyrolysis approach, synthesized from the four major processes currently under development (Purox, Torrax, "Flash" pyrolysis, and the LANDGARD System). Most of the systems require some degree of MSW processing (except Torrax) prior to MSW entering the pyrolitic chamber. The MSW processing train is assumed to be co-located with the pyrolysis unit and the sludge is assumed to be piped in and dewatered to 20 percent solids at the site. The fundamental concept of using heat from the thermal disposal of MSW to dry the sludge remains unchanged.

The unique features of pyrolysis are the reduced air requirements and the fact that the thermal decomposition process is endothermic rather than exothermic - in theory, there is no combustion at all. A distinct advantage of this approach is that the product of pyrolysis is a transportable fuel (either gas or oil) of low to medium Btu value which appears to be adaptable to existing fossil fuel firing systems. The addition of sludge to the system poses several problems. The major difficulty is that moisture in the sludge results in dilution of the end fuel product, lowering the overall Btu value. Further , drying the sludge consumes what would otherwise be exportable energy. If a direct drying system is used, an after burner may be necessary to destroy the odoriferous, moisture-laden drier exit gas, since its introduction into the pyrolysis chamber would be detrimental to the pyrolysis process and to the final fuel quality. The use of an indirect drier would require the addition of a waste heat boiler which would also drain saleable energy. There is a fundamental trade-off here, as in all of the energy-recovery systems, between selling recovered energy to an outside user and utilizing it for the drying of sludge. However, the successful European experience indicates that, under certain conditions and using proven technologies, energy recovery can be compatible with coincineration.

The refuse to sludge mixture ratios for copyrolysis are similar to the other thermal disposal alternatives. Historical data are non-existent (although both the Torrax and Purox systems have demonstrated technical feasibility), but Weston notes that for the Torrax system the input mixture should be at least 45 percent solids; while for the Purox process, the solids content can dropt to as low as 35 percent. These figures correspond to dry weight ratios of 4:1 (MSW to 20 percent solids MSS) and 3:1 (RDF to 20 percent solids MSS) respectively. Both systems would easily accommodate waste streams from equivalent populations.

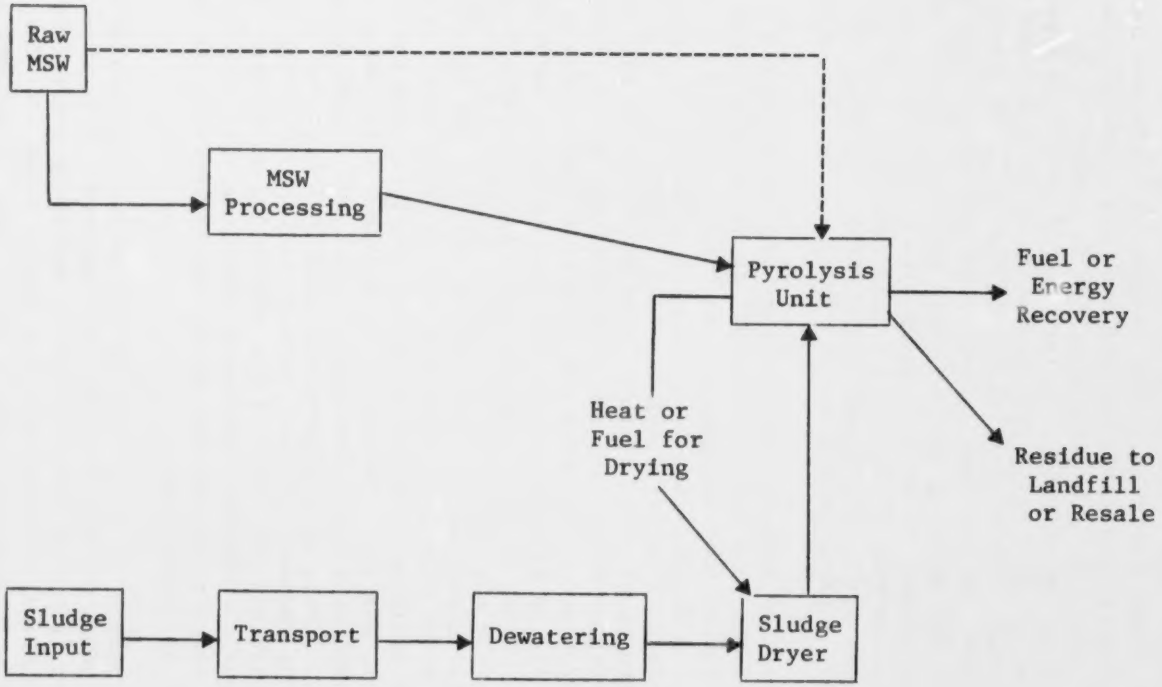
Raw MSW
MSW Processing
Pyrolysis Unit
Fuel or Energy Recovery
Residue to Landfill or Resale
Heat or Fuel for Drying
Sludge Input
Transport
Dewatering
Sludge Dryer

Figure 11. Copyrolysis.

Pyrolysis systems which produce only a fuel and do not combust it to produce steam or drier heat should have little difficulty in meeting air quality standards. Many of the potential pollutants are contained in the fuel itself and scrubber or baghouse filters should be capable of cleaning any remaining particulates from the in-house system exhausts. However, the addition of sludge to the system, with the requirement for fuel combustion in some form for drying, may necessitate more costly emission control equipment. Until full-scale facilities begin operation, many of these issues will remain unresolved and this technology should be considered developmental.

2.3.9 Summary and Conclusions. Eight of the more promising codisposal alternatives have been briefly examined here. Within certain mixing ration constraints, all are technically feasible, although none (except for landfilling) have been demonstrated in this country on a full production basis. Each system has both advantages and disadvantages, depending on the specific circumstances in which it is applied. One conclusion that is readily apparent from the analyses conducted in this report is the need for more empirical data concerning the actual processes. However, there are several other useful conclusions to be drawn from the data on hand.

The first is that, while landfill codisposal is one of the least expensive and most proven systems, the fact that it reduces rather than extends landfill life diminishes its problem-solving potential in the urban areas that are the most likely to have sludge and solid waste problems in combination. Consequently, landfill codisposal will not be emphasized in this study.

A further distinction is that several of these techniques are very compatible with existing facilities. Retrofitting existing MHF or FBF sludge incineration systems has been demonstrated and warrants further study in view of the large number of such furnaces currently in use. The solid waste thermal disposal systems can also be adapted relatively easily to handle sludge as well. However, all of the systems are more economical if originally desined for the purpose of codisposal.

Six of the eight processes are based on systems designed primarily for the disposal of MSW. MHF/FBF and composting are the only ones that are essentially sludge disposal oriented. For the MSS disposal systems, solid waste is employed as a replacement for an ingredient in the disposal process (i.e., bulking agent or fossil fuel), while for the MSW-based processes sludge disposal is an energy consuming, addition which has the potential to increase pollution control problems. On the other hand, the inclusion of sludge disposal in MSW systems may provide a built-in source of recovered energy revenues as well as possibility of partial Federal funding for facility construction under the Construction Grants provisions of the Clean Water Act. These distinctions are important from the cost allocation point of view, which will be discussed in the following section.

Landfilling and composting are the only viable non-thermal based processes, although composting involves many uncertainties. The main questions concern the quality of the product, the compatibility of MSW as a bulking agent, the effect of pending EPA regulations, and especially, the availability of a market for the product. Of the thermal codisposal options, copyrolysis is the most unproven. This situation stems directily from the as yet unresolved technological problems of the underlying MSW pyrolysis process. However, pyrolysis via MHF sludge incinerators appears promising as does coincineration in MSW waterwall or dedicated boiler systems.

The two systems with the most potential at present are the MHF/pyrolysis coincineration option as tested in Contra Costa County, California and the waterwall mass burning combustion process along the lines of the systems in Harrisburg, Pennsylvania and numerous European locations. These systems will be examined in more detail in the following chapter.

2.4 Economics of Codisposal

This section will examine the relative costs of specific codisposal systems as compared to alternative codisposal options. Again, due to the general nature of this analysis, no attempt is made to present these costs in detail. However, it is apparent that economics may be the pivotal argument in the decision of whether to commit to a codisposal process or to single purpose facilities. Therefore, the data developed here are presented to enable community decision makers to evaluate relative levels of cost for several different scale systems and to determine which approach, if any, is applicable to their specific needs. A brief general discussion of the economic trade-offs between solid waste and wastewater agencies is also presented.

The economics of each codisposal process are presented through the same general format. Two codisposal facilities are compared, a large and a small (TPD capacity), based on the feed ratios and moisture contents developed earlier. For those approaches which are constrained to narrow ranges of compatibility ratios, only one scale facility will be examined. Costs are broken down by source; those attributable to the MSW processing, the MSS processing, or those "other costs" not directly linked to either process. The most commonly encountered "other cost" arises from the need for additional sludge drying before it can be introduced to the solid waste-based thermal disposal process. The costs for direct and indirect sludge driers are based on the data developed in the Weston study.

Capital and annual costs for the individual waste processing streams are based on the figures developed earlier for single purpose systems. However, these costs are adjusted when the co-disposal approach involves savings or additional costs as noted in the specific process descriptions to follow.

For most solid waste based systems, a general additional cost is incurred by the requirement to transport the sludge to the site although with sufficient planning the wastewater treatment plant and solid waste disposal facility can be coloacted. The two major means of transporting sludge are by truck or by pumping through a pipeline. Rail and barge transportation are also feasible alternatives, but their applicability is so limited that they will not be considered here. Transporting by truck is more economical after the sludge has undergone dewatering, either to 20 percent or 40 percent soldis. Dump trucks are the commonly employed vehicle. Costs for an 80 TPD (dry weight) facility run $1.20 per dry ton mile based on an average 10 mile trip,* including capital costs.

In order to be pumped through a pipeline, sludge must be relatively liquid (no more than 5 percent solids). Pipeline capital costs are high but operating costs are small and the unit costs are, therefore, very sensitive to economies of scale. Total capital and operating costs for this approach range from $0.60 to $3.10 per dry ton (10 to 100 TPD) depending on the scale of the operation. Corresponding capital costs range from $100,000 to $200,000 per dry ton mile. An average pumping distance of 10 miles is also assumed; resulting in a total transportation cost of from $6.00 to $31.00 per dry ton of sludge, with capital costs of $1-2 million. As noted in an earlier section, this evaluation assumes dewatering to 20 percent at the codisposal site and transportation to that facility via pipeline for all codisposal options unless otherwise noted.

Perhaps the most important economic issue in the minds of many officials is the extent of federal funding available to codisposal projects under the Construction Grants (Sec. 201) provisions of PL 92-500. Some confusion has been generated by EPA's disparate handling of two current codisposal projects. For Contra Costa County, only those aspects of the solid waste processing which directly contributed to the MSS incineration process were considered eligible for grant money. In Duluth the entire project, including the RDF facility, was determined eligible. EPA, however, has stated that the Minnesota project is the exception and that future codisposal projects will receive funding according to a specific formula discussed in Chapter 3.

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*Consoer, Townsend, op. cit.

2.4.1 Landfilling. According to the ratios determined earlier, dewatered 20 percent solids sludge can be safely added to solid waste in a sanitary landfill at a dry weight ratio of one part MSS for 10 parts MSW. Accordingly, the costs presented here are for landfill codisposal facilities combining 100 tons of MSW with 10 dry tons MSS and 1000 tons MSW with 100 dry tons MSS. This ratio comes close to the equivalent population generation rate (13:1) and is representative of communities with populations in the range of 75,000 to 100,000 and 750,000 to 1,000,000, respectively.

The cost breakdowns for this approach are shown in Table 7. Capital and operating costs attributable to the solid waste process are unchanged from the single purpose system. The sludge related costs are based on aerobic digestion, dewatering to 20 percent solids via vacuum filtration, and truck transportation to the fill site. In Table 7 the costs for co-landfilling MSW with stabilized (aerobically digested) thickened sludge are shown. This approach eliminates the expense of dewatering. However, it is unclear at this writing whether the addition of 5 percent solids MSS will be economical in view of the potentially stringent requirements of pending RCRA guidelines.

According to the Oceanside, California data, the addition of sludge to the MSW sanitary landfill does not significantly increase operating costs. Therefore, no additional landfilling costs are included in the sludge processing train. However, it should be noted that pending EPA sludge disposal guidelines have the potential to substantially increase the costs of codisposal in an MSW sanitary landfill. At this writing, any attempt to specify the amount of increase would be speculative, so no additional costs have been presented for this process. It is apparent that as a result of the recently published RCRA landfill criteria, the annual, and especially capital, costs of landfilling in general (including codisposal) will be greater than is shown here.

The potential for savings with this approach over single purpose landfilling stems from the elimination of a separate landfill facility with its attendant capital costs and institutional obstacles. Also, annual costs are reduced by the smaller capital amortization costs and reduced operating costs. Clearly, no matter what the implications the RCRA guidelines, landfill codisposal should be considered as a viable sludge disposal alternative in areas where land is available.

2.4.2 Conventional Coincineration. The costs shown in Table 8 reflect the costs of constructing and operating a refractory wall MSW incinerator without heat recovery, fitted with a rotary drum type direct dryer to accommodate dewatered (20 percent solids) MSS. The large and small capacities are both shown at a 10:1 MSW to MSS ratio which approximates the equivalent population ratio and maintians autogenous combustion.

Major MSS expenses stem for dewatering and transport. MSW costs are unchaned from those of single-purpose facilities. It should be noted that increased costs due to more extensive residue handling and emissions control equipment are not included here. Measurements at the Krefeld plant indicate that the addition of sludge in refuse fired incinerators will significantly increase particulate emissions.

2.4.3 Composting Codisposal. The economics for the two major composting approahces are shown in Table 9. Part "a" of this table covers the static pile process, employing processed MSW with dewatered sludge in a 5:1 ratio. The individual costs are identical to the single purpose MSW (RDF) and MSS (composting) costs except that $10 per dry ton has been deducted from the MSS cost of composting to account for the replacement of wood chips with RDF as bulking agent.

The key to the economics of this system is that RDF is relatively expensive to produce, and using it as a replacement for a low value input such as wood chips is not an economical prospect. RDF combines the dry sludge at a 4:1 ratio so that, at this scale, the RDF bulking agent costs $100 per dry ton of MSS, vs. $10 for wood chips. Since RDF has a potential revenue value of $6/ton as an alternative fuel product. the opportunity cost of each dry ton of MSS is $24.* Even with the $10/dry ton MSS credit, the MSW facility is losing $3.50 per ton of RDF in fuel sales foregone. Of course, this analysis does not take into account revenues from the sale of the composted product.

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*USDA, Costs of sludge composting, p. 13.

TABLE 7

ECONOMICS OF LANDFILL CODISPOSAL

1a) MSW with dewatered sludge (20% solids) added:

Ratio of Design TPD Capacties (MSW:MSS)	100:10			1000:100		
Cost Source	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)†	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)†
MSW	$ 385	$ 8	$ 245	$ 2,400	$ 5	$ 1,530
MSS	1,900	147	450	11,500	101	3,091
Other Costs	NA	NA	NA	NA	NA	NA
TOTAL	$2,285	$21‡	$ 695	$13,900	$14‡	$4,621

1b) MSW with thickened sludge (5% solids) added:

Ratio of Design TPD Capacities (MSW:MSS)	400:10		
Cost Source	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)†
MSW	$1,185	$ 6	$ 734
MSS	1,250	114	349
Other Costs	NA	NA	NA
TOTAL	$2,435	$ 9 ‡	$1,083

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* Includes capital amortized over 20 years at 7%.

† Based on 306 days per year (6 days/week minus holidays).

‡ Represents total cost per ton of combined waste (MSW + MSS).

TABLE 8

ECONOMICS OF CODISPOSAL IN A REFRACTORY WALL SOLID WASTE INCINERATOR

Ratio of Design TPD Capacities (MSW:MSS)*	100:10			1000:100		
Cost Source	Capital Cost (10^3)	Cost/Ton [†]	Total Annual Cost (10^3)[‡]	Capital Cost (10^3)	Cost/Ton[†]	Total Annual Cost (10^3)[†]
MSW	$1,500	$ 15	$459	$ 6,500	$10	$3,060
MSS	1,850	107	327	8,000	55	1,683
Other Costs [§]	750	23	70	6,000	18	551
TOTAL	$4,100	$ 25 [¶]	$857	$20,500	$16[§]	$5,294

* MSS input is assumed 20% solids.

† Includes capital amortized over 20 years at 7%.

‡ Based on 306 operating days per year 96 days/week minus holidays.

§ Other costs include a rotary drum type direct dryer and all equipment necessary for sludge handling.

¶ Represents total cost per ton of combined wastes (MSS + MSW).

TABLE 9

ECONOMICS OF CODISPOSAL THROUGH COMPOSTING

3a) MSW processed into RDF and composted (static pile) with dewatered (20% solids) MSS

3b) MSW processed into RDF and composted (mechanical digester) with thickened (5% solids) MSS

Ratio of Design TPD Capacities (MSW:MSS)	250:50			1000:50		
Cost Source	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)[†]	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)[†]
MSW	$ 6,750	$19	$1,423	$17,000	$14	$4,162
MSS	4,500	84[‡]	1,285	3,150	42[‡]	642
Other Costs	NA	NA	NA	NA	NA	NA
TOTAL	$11,250	$30[§]	$2,708	$20,150	$15[§]	$4,804

[*] Includes capital amortized over 20 years at 7%.

[†] Based on 306 days per year (6 days/week minus holidays).

[‡] Does not include any revenues from sale of compost product.

[§] Represents total cost per ton of combined waste (MSW + MSS).

For this codisposal option to operate economically, the following conditions appear necessary: no source, or a very expensive source of bulking agent; a strong, lucrative market for compost; no market for RDF as fuel. However, the cost per dry ton of MSS for a bulking agent could be significantly reduced if a partially or coarsely separated RDF from a simple pulverizer were used.

Part "b" of Table 9 reflects costs of the mechanical digester process employed at a 20:1 MSW to MSS ratio with 5 percent solids sludge. The process appears very economical since MSS processing involves no more than thickening and transport to the compost site. However, until more data is provided through a full-scale facility, serious questions remain concerning the practicality of such a system.

2.4.4 Codisposal in an MHF/FBF. The economics for this approach are shown in Table 10; the costs for both systems are comparable. Again, it should be noted that the costs shown are for retrofitting existing units, so that in reality some capital costs of the incinerator may already have been incurred. The capacity ratios shown (2.5:1) are within the range of optimum furnace performance. but are much less than the equivalent population (13:1) proportions.

RDF is being used as fuel in the MSS furnace, thereby eliminating the need for $22/day for sludge in fossil fuel cost. Some $62.50 worth of RDF is required for each dry ton of MSS. However, with the fuel savings noted above, this codisposal system has a lower annual cost than a combination of comparably sized single purpose RDF and MHF/FBF systems.

It is reasonalbe to assume that the MSW facility would receive a credit from the WWTP that approaches the value of the MSS systems savings. If this credit equals or exceeds the RDF's value as a fuel in alternative markets, then the system might be attractive from both points of view. The economics of MHF/FBF codisposal therefore hinge on whether $15/dry ton of sludge ($6/ton RDF x 2.5) is saved by the WWTP by entering the system. However, other factors must be considered such as the wear and tear on the equipment, increased dust loadings and ash removal resulting from the incineration of RDF as opposed to a conventional fossil fuel.

A further consideration is the mismatch between the large MSS population usage required compared to the relatively small number of people needed to produce the proper input proportion of MSW. As RDF facilities are capital intensive, the tendency is to make them handle as much waste as possible to capture economies of scale. It may be possible to arrange to sell excess RDF to outside users, or alternatively, RDF facilities could consider other MHF/FBF operations as markets for thier excess RDF. In

TABLE 10

ECONOMICS OF CODISPOSAL IN AN EXISTING MULTIPLE HEARTH OR FLUIDIZED BED FURNACE

a) MSW processed into RDF and added to an MHF with dewatered (20% solids) MSS

Ratio of Design TPD Capacities (MSW:MSS)	250:100		
Cost Source	Capital Cost (10^3)	Cost/Ton*	Total Annual Cost (10^3)†
MSW	$ 6,750	$ 19	$1,423
MSS	18,500	119‡	3,641
Other Costs§	5,000	15	459
TOTAL	$30,250	$ 52¶	$5,523

b) MSW processed into RDF and added to an FBF with dewatered (20% solids) MSS

Ratio of Design TPD Capacities (MSW:MSS)	250:100		
Cost Source	Capital	Cost/Ton*	Total Annual Cost (10^3)†
MSW	$ 6,750	$ 19	$1,423
MSS	16,350	110‡	3,366
Other Costs§	5,000	15	459
TOTAL	$28,100	$ 49¶	$5,248

* Includes capital amortized over 20 years at 7%.

† Based on 306 days per year (6 days/week minus holidays).

‡ $22 dry ton MSS has been deducted from the single purpose operating cost to account for eliminating the need for fossil fuel (usually oil).

§ Includes cost of retrofitting furnaces to burn RDF.

¶ Represents total cost per ton of combined waste (MSW + MSS).

any case, the sizing must be resolved if this approach to codisposal is to be economically attractive.

2.4.5 Mass Burning Waterwall Coincineration. The large (10:1) and small (25:1) scale operations presented in Table 11 both represent technically efficient mixing ratios for this approach. That is, the energy balance contains enough Btus to dry 20 percent solids MSS and still export energy in the form of steam. The MSW and MSS costs shown are from the single purpose process except for the addition of sludge transportation costs and the "other costs." For the 250:10 ratio, this latter category includes $18 per dry ton MSS from the indirect dryer and related sludge handling costs and also $44 per dry ton MSS as the cost of the steam required for drying the sludge. This is based on 14,800 lbs. of steam required per dry ton MSS in an indirect dryer at $3/1,000 lbs. steam. This cost is based on the assumption that the waterwall facility charges the WWTP the same price it commands on the open market for the rest of its steam. These conditions are similar to the situation in Harrisburg, Pennsylvania. Note that these conditions may not hold true where the direct drying method is employed.

2.4.6 Dedicated Boiler. The conomics of this approach are shown in Table 12. Except for the differences in MSW processing costs, this system's economics are essentially the same as for waterwall codisposal.

2.4.7 Modular Combustion Unit. The costs for this approach shown in Table 13. The analysis is similar to the preceding waterwall and dedicated boiler systems. Only the scale, MSW costs, and the steam revenues vary from the previous discussions.

2.4.8 Copyrolysis. Table 14 displays the costs for two sizes of copyrolysis facilities, with MSW to MSS ratios ranging from 2:5:1 to 10:2. The MSW costs shown include revenues from fuel products sale, but not tipping fees. MSS costs are based on single purpose digesting and dewatering plus transportation to the site. Other costs are derived from Weston's indirect drier costs and from the costs of purchasing fuel from the pyrolysis system for drying the sludge. The $22/dry ton MSS is based on EPA estimates of the average Btu value of the pyrolysis fuel products and on Gordian's estimate of the Btu requirements (14.8M/ton) for drying. As this system is as yet unproven, the potential for error is high.

TABLE 11

ECONOMICS OF CODISPOSAL IN A WATERWALL FURNACE

Ratio of Design TPD Capacities (MSW:MSS)[*]	250:10			1000:100		
Cost Source	Capital Cost (10^3)	Cost/Ton[†]	Total Annual Cost (10^3)[‡]	Capital Cost (10^3)	Cost/Ton[†]	Total Annual Cost (10^3)[‡]
MSW	$12,200	$13[§]	$ 995	$37,000	$ 7[§]	$2,142
MSS	1,850	107	327	8,000	55	1,683
Other Costs [¶]	600	62[**]	190	4,500	58[**]	1,775
TOTAL	$14,650	$19[††]	$1,512	$49,500	17[††]	$5,600

[*] MSS input is assumed 20% solids.

[†] Includes capital amortized over 20 years at 7%.

[‡] Based on 306 days per year (6 days/week minus holidays).

[§] Includes revenues of $18/input ton MSW from sale of steam.

[¶] Includes costs of porcupine type indirect dryer and all related sludge handling costs.

[**] Includes costs of purchasing steam at $3/1000 lbs. for sludge drying.

[††] Represents total cost per ton of combined waste (MSW + MSS).

TABLE 12

ECONOMICS OF CODISPOSAL IN A DEDICATED BOILER SYSTEM

Ratio of Design TPD Capacities (MSW:MSS)*	250:10			1000:100		
Cost Source	Capital Cost (10^3)	Cost/Ton†	Total Annual Cost (10^3)†‡	Capital Cost (10^3)	Cost/Ton†	Total Annual Cost (10^3)†‡
MSW	$13,000	$19§	$1,454	$32,000	$ 9§	$2,754
MSS	1,850	107	327	8,000	55	1,683
Other Costs¶	600	62**	190	4,500	58**	1,775
TOTAL	$15,450	$25††	$1,971	$44,500	$18††	$6,212

* MSS input is assumed 20% solids.

† Includes capital amortized over 20 years at 7%.

‡ Based on 306 days per year (6 days/week minus holidays).

§ Includes revenues of $18/input ton MSW from sale of steam.

¶ Includes costs of porcupine type indirect dryer and all related sludge handling costs.

** Includes cost of purchasing steam at $3/1000 lbs. for sludge drying.

†† Represents total cost per ton of combined waste (MSW + MSS).

TABLE 13

ECONOMICS OF CODISPOSAL IN A MODULAR COMBUSTION UNIT (WITH ENERGY RECOVERY)

Ratio of Design TPD Capacities (MSW:MSS)*	50:10			100:10		
Cost Source	Capital Cost (10^3)	Cost/Ton[†]	Total Annual Cost (10^3)[‡]	Capital Cost (10^3)	Cost/Ton[†]	Total Annual Cost (10^3)[‡]
MSW	$1,250	$ 8[§]	$122	$2,000	$ 5[§]	$153
MSS	1,850	107	327	1,850	107	327
Other Costs[¶]	600	51**	156	600	51**	156
TOTAL	$3,700	$33[‡‡]	$605	$4,450	$19[‡‡]	$636

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* MSS input is assumed 20% solids.

[†] Includes capital amortized over 20 years at 7%.

[‡] Based on 306 days per year (6 days/week minus holidays).

[§] Includes revenues of $9/input ton MSW from sale of steam.

[¶] Includes costs or porcupine type indirect dryer and all related sludge handling costs.

** Includes cost of purchasing steam at $2.25/1000 lbs. for sludge drying.

[‡‡] Represents total cost per ton of combined waste (MSW + MSS).

TABLE 14

ECONOMICS OF CODISPOSAL IN AN MSW PYROLYSIS UNIT

Ratio TPD Capacities (MSW:MSS)*	250:1000			1000:100		
Cost Source	Capital Cost (10^3)	Cost/Ton†	Total Annual Cost (10^3)‡	Capital Cost (10^3)	Cost/Ton†	Total Annual Cost (10^3)‡
MSW	$12,500	$21§	$1,607	$33,600	$13§	$3,978
MSS	8,000	56	1,714	8,000	56	1,714
Other Costs ¶	4,500	36**	1,102	4,500	36**	1,102
TOTAL	$25,000	$41‡‡	$4,423	$45,100	$20‡‡	$6,794

* MSS input is assumed 20% solids.

† Includes capital amortized over 20% years at 7%.

‡ Based on 306 days per year (6 days/week minus holidays).

§ Includes $9/incoming ton MSW from sale of fuel product.

¶ Includes costs of porcupine type indirect dryer and all related sludge handling costs.

** Includes cost of purchasing energy for sludge drying from pryolysis process at $22/dry ton MSS.

‡‡ Represents total cost per ton of combined waste (MSW + MSS).

2.4.9 Summary and Conclusions. A summary of the economics for the major codisposal options is presented in Table 15. This table was prepared so that the costs of codisposal could be easily compared with the cost summaries developed earlier for single purpose systems. It should be noted that these systems are not directly comparable with each other due to variance in scale.

A major conclusion of this economics section is that codisposal can be seen to be competitive with most combinations of single purpose systems. Landfill codisposal is cheaper than all higher technology codisposal systems that involve landfilling as one process. However, as noted earlier, for most communities faced with MSW and MSS problems, landfilling is not one of the options open. Consequently, high technology codisposal is an economically sound alternative for urban areas with waste disposal problems.

For codisposal to be economically attractive, its implementation must involve a saving to either the MSW or MSS administration (providing the two are separate entities). This saving is the key to cost allocation between the two agencies. The amount of the saving and the agency to which it accrues dictate boundaries and bargaining positions for negotiations between institutions. As is frequently the case in Europe, one agency may be charged with both MSW and MSS disposal thereby elminating the need for bargaining. The leeway and the opportunity costs of alternative approaches are among the significant economic determinants. The remaining factor is the availability of Federal capital funding under the Construction Grants program of PL 95-217. That aspect is considered in the following chapter.

TABLE 15

SUMMARY OF COSTS FOR CODISPOSAL OPTIONS

	Capital Costs ($\$10^3$)		Total Annual Net Costs ($\$10^3$)†		Total Cost Per Dry Ton of Combined Waste (MSS + MSW)	
Codisposal Option*	Small	Large	Small	Large	Small	Large
Landfill						
Small - 100:10‡ 20% Solids Large - 1000:100 MSS	2,285	13,900	695	4,621	21	14
Large - 400:10 5% Solids MSS	§	2,435	§	1,083	§	9
Incineration						
Small - 200:10‡ Large - 1000:100	4,100	20,500	857	5,294	25	16
Composting						
Small - 250:50‡ 20% Solids MSS	11,250	§	2,708	§	30	§
Large - 1000:50 5% Solids MSS	20,250	§	4,804	§	15	§
MHF (250:100)‡	30,250	§	5,523	§	52	§
FBF (250:100)‡	28,100	§	5,248	§	49	§
Waterwall						
Small - 250:10‡ Large - 1000:100	14,650	43,500	1,512	5,600	19	17
Dedicated						
Small - 250:10‡ Large - 1000:100	15,450	44,500	1,971	6,212	25	18
Modular Incinerator‡						
Small - 50:10‡ Large - 100:10	3,700	4,450	650	636	33	19
Pyrolysis‡						
Small - 250:10‡ Large - 1000:100	25,000	45,100	4,423	6,794	41	20

* All processes are assumed to use MSW plus 20% solids MSS except as noted.

† Costs do not include tipping fees.

‡ All ratios refer to facility capacity in tons per day as received MSW to dry weight MSS.

§ For these systems, only one capacity range is applicable due to technological or economic limitations.

3. INSTITUTIONAL FACTORS AFFECTING CODISPOSAL

The technological and economic factors that bear on the potential viability of codisposal have been examined in previous sections. This chapter explores a third distinct family of equally important considerations that have been labelled, for lack of a more precise term, institutional factors. The term "institutional" refers to the complex legal, organizational and administrative factors that determine the framework within which wastewater and solid waste management operate. Specific aspects of each of these institutional factors are discussed in this chapter. The purposes of the discussions are to:

1. Identify legal, organizational and administrative features of wastewater and solid waste management that appear to be impediments to codisposal.
2. Suggest how these obstacles might be avoided in planning or implementing codisposal projects.

Two points should be borne in mind. First, institutional considerations differ from project to project because of disparities in local and state laws or because of differences in the nature of wastewater and solid waste agencies from one municipality to another. Second, the importance of institutional factors depends on whether a project can be seen as technically or economically feasible. It will eventually be necessary for those involved in codisposal projects to look at each codisposal project on its own merits; since this study is not focused on specific projects, the concepts are generalized.

In broad terms, the apparent institutional problem areas in codisposal fall into two main groups, as follows:

- Inherent organizational differences between water and solid waste management programs, specifically with respect to planning and financing of codisposal facilities. These differences are an outgrowth of the trends in program devleopment in these two areas in the U.S. They encompass not only differences in purpose and function, but also related differences in organizational structure and administration at all levels of government. The discussion that follows points out that, as a practical matter, these divergencies constitute obstacles primarily to integrated project planning, not to operating a project once it is conceived, planned, funded and constructed. If basic differences can be satisfactorily overcome in the planning stages of a project, they will not obstruct operations.

- Legal issues, such as waste control and coordination of the complex mix of public and private interests in solid waste handling and disposal. These issues are seen as obstacles because they are key elements in the foundation for proper project planning. Further, they are issues that must be specifically addressed at several levels of government. However, these legal issues are generally no more of an obstacle than if single purpose resource recovery or wastewater treatment projects are being addressed.

3.1 Organizational Issues

As separate public works programs in the U.S., solid waste management and water quality management have not developed in parallel, so that today the two programs display fundamental differences at all levels. A list of some key differences appears in Table 16, which shows that disparities are manifest in the mission, structure, function, authorities, financing, capitalization, staff and operating modes. These disparities stem from the different evolutionary processes which have formed the two distinct programs as they now exist.

Water quality management programs were initiated as a local public health concern; the emphasis on protection and eventual improvement of the nation's waterways is a relatively recent development of federal policy. Stream quality is now the primary thrust of most water quality management programs. Particular concern over potential problems of sludge disposal is only now emerging as a result of continual growth of nationwide treatment capacity.

Municipal wastewater treatment has also evolved as a wholly public function. Widespread secondary and advanced treatment requires capital-intensive facilities. To construct these facilities, a sizeable federal grant program* was established to assist in financing. Grants under the Federal Water Pollution Control Act are made available to public agencies, and corollary requirements of the program have created a complex system of state, areawide, and local water quality agencies. The effect of these program requirements has been the creation of municipal or regional public bodies, vested with considerable responsibility and authority to carry out the planning and financing required to establish and run a wastewater treatment facility.

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*Federal Water Pollution Control Act, as amended - Construction Grants program, P.L. 95-217 (40 CFR 35).

TABLE 16

SOME KEY DIFFERENCES BETWEEN WASTE WATER AND SOLID WASTE MANAGEMENT

Waste Water Management*	Solid Waste Management
Focus is mainly on disposal of a liquid waste in a receiving waterway.	Focus is mainly on land disposal of a solid waste product.
High capital requirements for wastewater treatment.	Typically capitalized at a lower level.
Large, well-developed Federal grant program underway with complex state, areawide and local planning requirements.	Limited financial assistance, varied planning requirements, emerging government regulation.
Municipal facilities are almost entirely owned by public sector.	More than 50% of activity is by private operators.
Broad planning functions usually carried out by an areawide wastewater management agency.	Planning is historically less sophisticated, more fragmented; broad planning done at the state level, local planning ususlly handled perfunctorily by individual municipalities or counties according to "least-cost" criterion.
In many cases, a separate organization exists to plan, finance and own individual facilities.	In many cases, these functions are vested in an integral municipal or county agency with more limited functions and possibly other responsibilities.
Service organized according to hydrologic boundaries.	Typically organized according to local political boundaries.

* Under the Clean Water Act of 1977, P.L. 95-217.

The organizational development of solid waste management, on the other hand, has progressed along different lines. While being a public health concern, solid waste management has traditionally been handled by the individual waste generator -- the household, factory, institution, etc. Further, where the focus of wastewater treatment is on effluent and stream quality, the focus of solid waste management has been mainly on removal of the waste to a dump or landfill.

Following the increase in population levels and densities, much of the collection, hauling, and disposal functions of larger cities and towns had to be performed in some centralized manner. This has led to the growth of private waste hauling and disposal industries in the United States. Unlike wastewater treatment, the different components of solid waste management (i.e., collection, transport, processing, storage, disposal) can conceivably be handled by different concerns, and in most places in the U.S. have never been handled by one authority. At this time, well over half of America's cities have their residential waste collected by private carters.*

A federal grant program similar to that established for wastewater treatment has never been established to help finance local solid waste management, due in part to the far lower levels of capitalization required and also due to the potential for interference with private operations. Consequently, solid waste management has developed far less centralized activity than wastewater programs. The various planning and financing functions are instead vested in a melange of different groups, some public and some private.

3.1.1 Planning Constraints. The evolution of two separate programs for wastewater and solid waste management has influenced the creation of distinct, separate program structures. Within each structure, planning activities are guided by different requirements and objectives.

In terms of economics, both programs are aimed at cost minimization. However, since federal grants are available for a significant proportion of capital costs, sewage treatment planning emphasizes the minimization of locally supported operating costs, often substituting capital items in favor of added operating expense. Virtually all solid waste project costs must be borne locally, so that the emphasis has typically been on the lowest cost mix of capital and other factors of production, often resulting in labor- or land-intensive processes. Where high capital solid waste processes have been recently installed, the basis of economic planning has been revenues from resources or energy recovery rather than the availability of capital grant funding. This is a significant barrier, in that codisposal largely means capital intensity. While high levels of capitalization are typical of sewage treatment, they are less so in solid waste management. Naturally, this introduces difficulties into financing facilities. However, it also makes planning difficult, in that the planning process for high capital solid waste facilities is considerably more complex that that required for more typical operations, such as landfilling. This additional complexity creates an immediate demand for greater human, technical and data resources, as well as for greater funding levels.

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*E.S. Savas, 1977. Of a large sample of cities surveyed, 66 percent are served at least partially by private haulers, while 57.8 percent are served exclusively by private firms.

Similarly, the nature of facilities planning differs between th two programs. In the interest of cost-effectiveness, the Construction Grants Program has sponsored considerable refinement and standardization in process design for wastewater treatment. In addition, the 201* planning process specifies that the grant applicant demonstrate a cost-effective selection of processes. The "cost-effective" analysis looks at a number of factors, including unit costs, reliability, ease of operation and environmental impact. Codisposal, as a relatively new application of technology, is at a disadvantage in this procedure, since the technology has not been demonstrated to the extent that it is seen as a "standard" process option among 201 applicants or their engineer-planners.

As mentioned previously, the geography of solid waste and wastewater management concerns do not naturally coincide. Not only are wastewater functions planned according to hydrologic boundaries as opposed to municipal ones, but treatment plants are also typically sited downstream from population centers, near the planned outfall location. Sites available to meet these water-related criteria may not be well located for solid waste handling. It can also be seen from the discussion of codisposal processes that the viable scales of operation do not lend themselves in all cases for servicing the same geographic area or population base. To some extent (e.g., joint siting and the need to organize sewage collection for maximum gravity flow), these are practical problems that can be worked out during planning once a commitment is made to consider codisposal. However, they also represent real institutional issues in that the designation of joint service area boundaries requires an overview level of planning that is not usually found in the individual plans of two separate organizations. Area-wide water quality management planning under Section 208 operates at this overview level, but does not include any solid waste planning mandate.

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*Section 201, P.L. 95-217, ibid.

This issue is apparent in at least two current examples of codisposal planning.* In Duluth, Minnesota, the refuse collection area includes customers who are not connected to the sewer system; a problem arises in settling how to charge these customers for the increased costs of codisposal. In Minneapolis, the planning for codisposal that was undertaken by the Waste Control Commission found that competing resource recovery projects in other parts of the Twin Cities threatened to absorb the refuse available for codisposal. In consideration of these competing demands (as well as a number of system-specific technical and cost issues), the project was abandoned.

Another major organizational barrier to planning lies in the difference between a completely public wastewater program and a partly public, partly private solid waste activity. Apart from legal issues, this interferes with planning in that private operations have no incentive to plan or operate jointly. Further, public agency planning that has an impact on local private entrepreneurs must be carried out with attention to securing their support and preserving their livelihood.

The planning requirements for wastewater treatment facilities also differ significantly from those for solid waste facilities. The 201 Construction Grants Program proceeds through a three step planning process, from initial study through design to construction. The allocation of grant funds in each step is governed by a priority list established in each state. The criteria for assigning priorities are closely specified and are based generally on the severity of the pollution problem and the size of the affected population. Thus, Construction Grant applications that include codisposal must compete against other water quality problems to reach a position on the priority list where funds are available. The emphasis in priority assignments is on first meeting unfilled treatment needs.

Solid waste planning is not bound so closely to an outside schedule, since federal funds are not involved as often, nor are available planning funds distributed in the same manner. Solid waste planning schedules will be governed by the problems of developing project feasibility and financing. Where resource recovery is involved, the time required to develop firm markets would be an equally significant factor.

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*See Chapter 4 for a more detailed discussion of these two projects.

Meshing the two schedules would involve careful coordination at local, state and federal levels of planning. Of these three levels, the local planning agencies are the most important, for two reasons. First, the motivation for considering codisposal should originate locally. Second, in the absence of strong solid waste funding programs at both state and federal levels, there may not be sufficient program coordination to ensure that schedules can be brought together.

In summary, a comparison of wastewater and solid waste management planning is characterized by different economic objectives, different facility design and process selection criteria, different geographical coverage and process scales, and different degrees of public-private involvement. In several of these areas, the differences point to joint planning on a regional or areawide level as the appropriate approach to problem resolution.

3.1.2 Financing. Capital financing for wastewater treatment is a combination of federal, state and local public funds, plus private capital contributions for specific elements of the system (through the Industrial Cost Recovery program). For the treatment works and major interceptor sewers, eligible capital items may be 75 percent funded by a federal grant under the Clean Water Act.* The remaining 25 percent is provided by state and local sources in shares that vary from state to state. The state share may be provided as a grant or as a low-interest loan, while the local share is in most cases raised by general obligation or revenue bonding. For collection facilities other than major interceptors, funds are also provided locally from bonded indebtedness or from assessments against individual property owners.

Operating costs are not subsidized by grant funds; they must be generated locally by user charges. These charges must be sufficient to cover all current costs of operation, maintenance and repair, as well as to provide funds to retire local bonds and any other capital debt, such as low-interest loans.

Solid waste management activities are funded in a different manner. The most important difference is that limited federal funds are available only for project planning, not for capital financing. In addition, there is a greater presence of private risk capital in application to both collection and disposal activities. Thus, the potential capital funding mix includes local public funds, perhaps augmented with state-level funding assistance, and private funds from entrepreneurs operating solid waste handling concerns.

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*Several exceptions to this funding percentage are possible, notably the availability of 85 percent funding for certain innovative or energy saving treatment processes.

A second basic difference is in the origin of solid waste operating and debt retirement funds. Collection, hauling, and, to a degree disposal are covered by user charges. However, for costly solid waste disposal operations, project funding relies on revenues potentially available from the sale of recovered resources or energy and from the disposal fee. The expectation of these revenues is often the basis of planning for high technology solid waste facilities, where materials on energy revenues are planned to offset increases in the total cost of disposal; without these revenues, the facility would not be feasible. The key to assuming sufficient income from the sale of recovered energy or materials lies in successful market development. In effect, in a project involving energy recovery, codisposal is likely to be subordinate to the need to serve the energy market. For example, if providing the maximum volume of available steam is a central issue in negotiations between the energy producer and the steam purchaser, then codisposal may be deemed impractical, as it may be a net user of recovered energy under some conditions.

Perhaps the most important issues in codisposal financing revolve around the problems of cost allocation both for capital and operating costs. Each of these cost categore is made up of three components, if codisposal is viewed as the union of two otherwise separate activities. One component consists of the costs attributable solely to solid waste handling activities; the counterpart to these are the costs attributable solely to sludge handling. The third element of cost comprises the joint costs, which refer to those parts of the process that handle both sludge and solid waste. The two direct cost components are relatively easy to account for, but there is no clear-cut way to allocate the joint costs. Never-the less, if two separate agencies exist, or if the project serves two different populations, the cost must be allocated between the two so that capital financing proportions and user charges can be developed. Capital cost allocation is particularly important in establishing the part of project funds that can be provided by an EPA Construction Grant.

At this writing, EPA is in the process of establishing a new policy for capital cost allocation. Under the former policy, joint costs were allocated between solid waste and wastewater treatment according to a concept and formula* developed for allocating the costs of multiple purpose water resource projects. The concept was based on the presumption that the cost of a multiple purpose project would be less than the total cost of two single purpose projects. The formula procedure was essentially a standardized method for allocating joint project costs in proportion to the savings realized in each purpose of the multiple purpose project. In codisposal, joint costs were those incurred for the simultaneous incineration of MSS and MSW, or those incurred to produce RDF for sludge burning. It is not yet clear what form EPA's new policy will take, but the Agency's Wastewater and Solid waste offices are both hopeful that an incentive for codisposal will be provided.

The other aspect of codisposal project financing is the allocation of operating costs. This allocation must be made so as to split the cost of joint processing between the solid waste and the sludge agencies. Another factor in allocation may be the division of charges between those customers served by both processes and those served by only one. This allocation is not likely to be a significant difficulty, since operating costs can be divided according to the division of capital costs for funding purposes.

Whether EPA's eventual funding policy is a disincentive to codisposal appears to depend upon the type of project under consideration and the nature of the agencies sponsoring the project. For codisposal processes that are primarily for solid waste disposal such as large scale energy recovery, the funding policy is a trivial barrier, if any at all, for two reasons. First, the solid waste facility should be feasible in its own right. Since sludge disposal is usually a large energy user, it is basically just a part of the facility's energy market. If the Contruction Grants funding policy will assist the sewer agency in financing the equipment to deliver and prepare the sludge for incineration, the capital funding is not an issue to the agency financing the energy recovery facility.

However, codisposal may not appeal to the solid waste agency if the cost of solid waste handling increases as a result, or if codisposal involves only a part of the solid waste stream. Under these circumstances the cost allocation policy is a key issue, since the total cost of solid waste handling is entirely dependent on the extent to which EPA funding will assist in the cost of processing.

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*U.S. EPA, Construction grants program requirements No. PRM 77-4.

It should be noted that the pending cost allocation procedure is distinct from EPA's funding policy for financing "alternative and innovative" treatment processes. Under this policy.* several advantages may be available in considering alternative or innovative processes such as codisposal. The first is that EPA may allow for the present worth cost of such processes to be as much as 15 percent higher than the most cost-effective traditional process and the alternative process can still be eligible for a federal grant. Further, the grant may be as much as 85 percent charged against special funding allocations in each state. To account for the added risk, EPA will pay up to 100 percent of the cost of process replacement if failure should occur within two years of project start-up.

EPA is studying the possibility of revising the cost allocation procedure in order to cover multi-purpose projects (such as codisposal or wastewater reuse) on the same terms as other, single purpose innovative processes. One option is to establish the limit of grant eligibility according to the cost of the cheapest single-purpose alternative. The 15 percent premium could also be added to this cost. The effect of this policy change would be to increase the grant eligible funds in codisposal, thereby reducing the solid waste shares of project capital outlays. The new policy is expected to be issued in early 1980.

3.2 Legal Issues

Control of the sold waste stream is a critical element in planning codisposal projects. Sewage sludge is controlled by the municipal or regional authority as part of its responsibility for the environmentally proper handling of sewage. However, the more fragmented, partially public and partially private handling of solid wastes results in a less clear picture of solid waste control for the public sector. Since a prerequisite of any solid waste resource recovery system is the assurance of a steady waste supply, municipal solid waste must be controlled in some fashion by the concerned public agency.

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*43CFR 44022, Sep. 27, 1978.

In some municipalities, the collection and disposal of solid waste is a public function, and in such cases, effective public control of the waste stream already exists. However, almost twice as many cities in the U.S. have their residential refuse collected not by public employees but by private collection firms.* In these cases, waste control can be achieved in one of two fashions: by offering a tipping fee at the public facility which is lower than competing landfills or other area disposal alternatives; or by legislating, at the local or state level, public control of the municipal waste stream.

Currently, the least controversal means of achieving public control of the waste stream is by offering a lower tipping fee at the disposal facility. This is a less dependable form of waste control than actual ordinances or state laws, as reflected in the fact that mortgage bankers will often encourage municipalities to seek some form of legal waste control prior to revenue bond financing for solid waste processing facilities, with the argument that such arrangements significantly reduce the long term risk involved in such projects. Public control of the solid waste stream can be legislated in one of two fashions: by instituting flow control of the waste or by actually stipulating public ownership of the waste.

Flow control is currently the more prevalent of the two methods; it requires that the solid waste set out by residents for collection be delivered to the municipality's facility(ies) by the private refuse haulers, although the solid waste is not the property of the municipality. Such an arrangement has thus far been legislated by the State of Florida; the City of Akron, Ohio; Monroe County, New York; Jefferson County (Louisville), Kentucky; and the Western lake Superior Sanitary District in Duluth, Minnesota.

The second method, which at present has been legislated in the U.S. only by the State of Wisconsin, is actual ownership of the waste stream by the municipality. Figure 12 gives an example of a statewide waste ownership law as proposed in the General Assembly of the State of Indiana. Waste control legislation in effect ensures the municipality's access to a steady supply of municipal solid waste for the life of its processing facility. However, municipalities and states are likely to encounter varying degrees of resistance from the private waste hauling and disposal industries when trying to enact such enabling legislation.

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*E.S. Savas, Policy analysis for local government: public vs. private refuse collection.

Under either type of waste control legislation, private waste haulers and landill operators can be subjected to an increased degree of public control. The industry's feeling, if it can be generalized, is that such levels of control diminish or eliminate any profit incentive to the local operators by limiting their disposal options and therby disallowing the negotiation of lower tipping fees at area landfills. In addition, both types of flow control laws may also effectively remove any private recyclers and scrap dealers from the loop by requiring direct delivery to the municipal facility. In the extreme case of municipal waste ownership, the haulers are reduced to providing a strict public service, and are subject to regulation as public utilities under the law.

The waste control issue is currently being challenged in Federal District Court in the case of Glenwillow Landfill, Inc. et al. v. City of Akron et al.* The City of Akron, Ohio, which enacted flow control legislation in order to facilitate the establishment of an areawide solid waste resource recovery facility, is being challenged by Glenwillow Landfill, Inc., a private landfill operator, as to the constitutionality of the law. The legal issues involved which define this case as a Federal Constitutional concern are described below:

- Interstate Commerce of Recyclables - recycling materials from municipal solid waste is considered a form of interstate commerce, as is some hauling and disposal of solid waste by private operators. Such activities are thus regulated by a large body of federal statutes which cannot be preempted by local or state legislation. The plaintiff in this case argues that Akron's flow control law amounts to an unconstitutional infringement on interstate commerce activity.

- Anti-trust Violation - the plaintiff argues that the City is violating the Clayton Act by establishing a monopoly over a given area of commercial activity.**

Glenwillow Landfill, Inc. et al. v. The City of Akron is now in the late discovery state, and is expected to move to trial in the near future. It is unclear at present whether the City will be successful in defending the constitutionality of its law.

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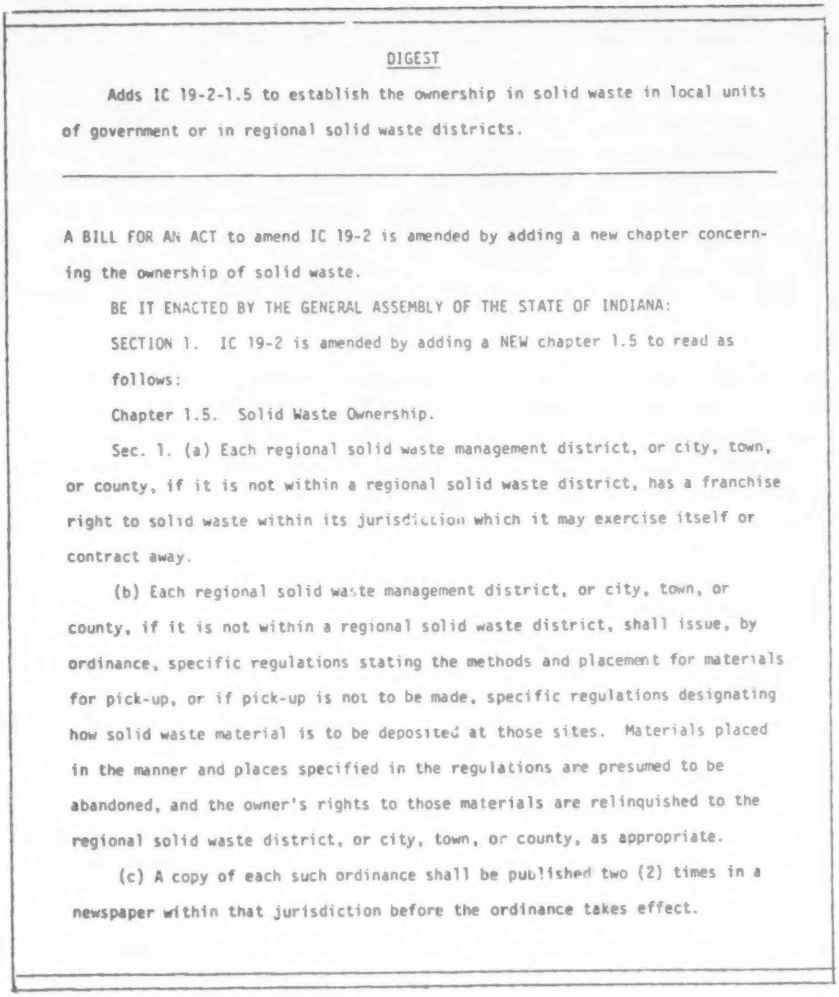
*Case C 78-65A of the Northern District, Eastern Division, of the Federal Court of Ohio.

**A significant body of legal precedents exists which defines the hauling, processing and disposal of municipal solid waste as a form of commerce.



DIGEST

Adds IC 19-2-1.5 to establish the ownership in solid waste in local units of government or in regional solid waste districts.

A BILL FOR AN ACT to amend IC 19-2 is amended by adding a new chapter concerning the ownership of solid waste.

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF INDIANA:

SECTION 1. IC 19-2 is amended by adding a NEW chapter 1.5 to read as follows:

Chapter 1.5. Solid Waste Ownership.

Sec. 1. (a) Each regional solid waste management district, or city, town, or county, if it is not within a regional solid waste district, has a franchise right to solid waste within its jurisdiction which it may exercise itself or contract away.

(b) Each regional solid waste management district, or city, town, or county, if it is not within a regional solid waste district, shall issue, by ordinance, specific regulations stating the methods and placement for materials for pick-up, or if pick-up is not to be made, specific regulations designating how solid waste material is to be deposited at those sites. Materials placed in the manner and places specified in the regulations are presumed to be abandoned, and the owner's rights to those materials are relinquished to the regional solid waste district, or city, town, or county, as appropriate.

(c) A copy of each such ordinance shall be published two (2) times in a newspaper within that jurisdiction before the ordinance takes effect.

Figure 12. Example of waste control legislation - Waste Ownership Act. Source: Draft prepared by the Indiana Solid Waste Management Commission, August 30, 1978.

A recent decision of the U.S. Supreme Court, however, may have significant implications on the anti-trust issue for the above case and future waste control legislation. The Supreme Court's decision, handed down in the Spring of 1978 in the case of Lafayette v. Louisiana Power and Light Company, states that municipalities do not have the same exemption from the Clayton Act's anti-trust provisions that states are allowed by the terms of the Act. This sets legal precedent to the effect that cities cannot create monopolies. Such a precedent indicates that any future waste control legislation might have to be enacted on a statewsie basis; even this is contingent upon a ruling in the Akron case that waste control legislation in general is not offensive on interstate commerce grounds. Statewide laws, of course, are considered by the private waste management industry to be fully as threatening, if not more so, than local statutes, for all the same reasons enumerated here. These can be expected to meet with varying degrees of resistance and legal challenge in the future.

To add to the dilemma of waste control facing many municipalities, some private carters or landfill operators will hold long-term contracts for handling of a municipality's waste, preventing enactment of waste control legislation until the contracts can be renegotiated or allowed to expire.

3.3 Conclusions

The most significant institutional issues affecting codisposal relate to project planning and financing, and to the basic legal formulations of solid waste management. The perspectives and opportunities for resolution of these three problem areas are different, as explained below.

3.3.1 Legal and Market Structure Issues. The legal issues of waste control and coordination with private market operations are pervasive and fundamental, overshadowing the prospects of codisposal in general (as well as other high technology solid waste disposal techniques), without regard to specific projects. The resolution of these issues is likely to depend on evolving policy decisions and legal precedents, rather than on *ad hoc* arrangements at the project level.

It is beyond the scope of this analysis to address the question of whether broader public involvement is desirable in the areas of solid waste collection, hauling and disposal. Nevertheless, it is an important question. Codisposal means high capital cost and complex technology in solid waste handling; these two characteristics indicate increase public regulation and ownership. Given the relatively informal and minimally capitalized nature of private municipal refuse disposal in most areas, a trend toward greater public control or ownership will bring considerable pressure to bear on traditional market structures and arrangements.

The presence of private enterprise raises certain obstacles to codisposal, but at the same time, private capital and private entrepreneurs are essential to the financing and implementation of resource recovery (and hence codisposal). Thus, care is important in establishing the limits of public authority over solid waste handling. A number of approaches are available for preserving the options of private initiative. These include the following:

- Use of market incentives to control waste flow
- Use of full-service arrangements for facility implementations
- Use of public funds to reduce the risk inherent in the application of new technologies

3.3.2 Planning Constraints. The majority of codisposal planning obstacles originate in the basic differences between solid waste and wastewater management. It appears that a number of these obstacles can be dealt with by approaching codisposal planning functions at a regional level. This would have several advantages. First, it would allow solid waste and water quality managment concerns and hierarchies to be integrated at the level of the 208 agency or the A-95 planning agency, where other regional issues (population growth, land use, transportation, environmental protection, etc.) are under more or less continuous review. Second, it would create an overview sufficiently broad to identify possibilities for solid waste management and codisposal at the most economical scales. Third, if a project were proposed that involved multiple jurisdictions, the regional agency would be a form for discussion of regional arrangements for funding or implementation.

The development of an overview level planning procedure would assist in coordinating dialogue among planners at the project level and above. However, another important aspect of planning is data to support dialogue and decisions. In this regard, codisposal is at a disadvantage. It will be necessary to develop a steady flow of technical and economic information about the technologies of the projects planned or underway, and the evolution of federal and state wastewater and solid waste management policies.

3.3.3 Financing Alternatives. Since the codisposal of municipal sludge and solid waste may involve wastewater treatment works and Construction Grants funds, the central issue is the policy for cost sharing under the Clean Water Act. As discussed previously, a new EPA cost allocation policy is imminent and it is hoped that any new policies would be designed to allow the 115 percent premium and 85 percent funding for codisposal as an "alternative/innovative" technology. In this regard, the funding policy would not appear to constitute a definite barrier to codisposal projects. However, it is useful to examine project financing from other viewpoints to see whether other policy arrangements within the limits of the Construction Grants program are relatively more conducive to codisposal.

Considerations of Economic Theory. For the most part, economic theory offers very little useful guidance for the allocation of costs in multiple purpose projects. This is particularly true of codisposal. The reasons for this are primarily the following:

- The most widely used economic criterion, that of "economic efficiency," is of no practical value in guiding allocation. To achieve economic efficiency, it is necessary to equate the marginal social cost of waste disposal with marginal benefits in order to find the optimum level and type of solid waste and sludge disposal. While some measures of marginal cost could be estimated, it is now easy to estimate the marginal social benefits of waste management. Besides the fact that many benefits cannot be quantified or evaluated, the benefits of the two programs do not accrue to the same groups of people. Essentially all that the efficiency criterion dictates is that codisposal should be cheaper than the cost of single purpose disposal; if no cost savings are possible, do not codispose.

- Without information regarding benefits, there is no useful method in economic theory that will pinpoint the "proper" relative shares of joint project costs. Thus, allocation of the costs that relate to joint processes (and also the savings from codisposal) is a matter to be decided by negotiation or by a policy rule. EPA's former cost allocation policy, termed the "Alternative Justifiable Expenditure" procedure (AJE) is such a policy rule, as are the revised allocation procedures now under consideration.

Other Criteria for Policy Evaluations. In the absence of a theoretical basis for cost allocation, the next best guide is to assess alternative cost allocation procedures against several simple rules. With respect to these, a cost allocation policy should:

- Help to achieve EPA's stated goals. The most definite goal statement is found in the policy that encourages alternative and innovative processes, including codisposal and energy efficient processes. The constraining policy is that EPA is not empowered to spend Clean Water Act funds for solid waste disposal purposes. However, as the policy is now structured, it does allow funding for a portion of a codisposal project.

- Encourage least-cost wastewater treatment and residuals handling. The cost-effective analysis required in 201 planning should ensure this, along with the natural incentive for local agencies to minimize their costs.

- Encourage least-cost solid waste disposal processes. While EPA is restricted from funding solid waste disposal under the Clean Water Act, its policies should not tend to increase the cost of this essential service. This implies that cost allocation should promote the most economical scale for processing of both wastes. It also implies that all sources of project revenues and financing should be taken into account.

- Be equitable and consistent in application. These are useful characteristics for any public funding program. They require that the funding policy be clearly stated and be based on the same data from project to project. It could be difficult to achieve consistency in codisposal funding, since the viable processes differ considerably in technology, scope and cost. Using these criteria, and looking at codisposal in terms of the mechanics of financing, it is possible to construct an alternative approach to EPA' funding posture.

An Alternative Cost Allocation Procedure. In codisposal, costs are incurred to deliver and prepare wastes for processing, to process the combined waste flow, to market recovered resources, and to dispose of residuals. Revenues are available from solid waste and wastewater user charges and from the sale of recovered resources. Financing is a matter of matching revenue sources with cash needs for operation, maintenance and debt service.

Each participant in the codisposal project has some limited financial capacity to contribute to capital and operating costs. As a practical matter, for each participant, this limit is equal to the cost of the next cheapest available alternative. Within these limits, and considering project revenues, many financing schemes can be worked out.

Table 17 summarizes the limits to financial participation in the 1000 TPD waterwall incinerator discussed previously. It can be seen in Table 18 that when the financing available within these limits is applied to the hypothetical project, a potential surplus exists among all sources. This surplus is an artifact of the cost of alternative sludge disposal in a multiple hearth furnace, but it should be borne in mind that codisposal is favored because of its advantageous total cost. Therefore, other available options should generally be more expensive.

This single example is by no means conclusive. Its purpose is simply to demonstrate the effect of approaching EPA funding as though the agency were a financing partner in the venture. With this approach, even the restricted 75 percent funding available as EPA's contribution to the MHF alternative is sufficient to approach what appears to be adequate financing. However, there are a number of implicit features of this approach, both pro and con, as follows:

Pro

- Recognizes the importance of project revenues.
- Based on alternative costs.
- Maximum flexibility.

Con

- May not be implementable under PL 95-217.
- Should be based on a full 20-year cash flow analysis.
- Would require a separate detailed analysis of each case.

TABLE 17

SUMMARY OF AVAILABLE FINANCIAL SUPPORT FOR CODISPOSAL - 1000 TPD WATERWALL INCINERATOR, 100 TPD SLUDGE

Project Participants	Limits of Financial Support	
	Nature	Amount
Solid Waste Agency	• Maximum tipping fee	$ 7-12/ton
	• Revenues from sale of energy and recovered materials	$18/ton for steam $ 3 ton for materials
Local Wastewater Agency	• O&M cost of next most cost-effective sludge disposal option (assume MHF)	$2,540,000/yr.
	• Local share of capital cost (25%)	$4,875,000
EPA	• Either	
	a) 75% of capital cost of MHF, or	$14,625,000
	b) 85% of 115% of MHF capital cost	$19,061,000
Local Energy User	• Unit price of alternative energy source	$2.50-3.50/1000 lbs. of steam

TABLE 18

ANALYSIS OF FUNDING SOURCES - 1000 TPD WATERWALL INCINERATOR, 100 TPD SLUDGE

General Elements of Cost		
Capital Cost	$ 43,500,000	
Present Worth O&M Cost	74,179,000	(20 years @ 7%)
Total	$117,679,000	
Available Funds*		
Steam Revenues (1000 TPD @ $18/ton)	$ 58,352,000	
Tipping Fee (1000 TPD @ $7/ton)	22,692,000	
O&M Cost, MHF	22,908,000	
Capital Cost, MHF		
Local Share @ 25%	4,875,000	
EPA Share @ 75%	14,625,000	
Total	$127,452,000	
Surplus/(Deficit)	$ 9,773,000	

Potential Uses of Surplus

- Reduce EPA share to $4,852,000.
- Reduce Local share to zero and MSS O&M cost by $15/ton.
- Reduce tipping fee to $4/ton.
- Reduce steam price to $2.50/1000 lbs. from $3.

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* Steam revenues, tipping fee, and O&M cost are shown as the present worth over 20 years at a 7% discount rate.

The limitations of the Clean Water Act may well be the deciding limitation. But in any event, such an analytic approach, as shown simplistically in Table 18, or in a more detailed cash flow format, would be a useful planning tool.

4. IMPLENTING CODISPOSAL

4.1 A Few Real World Situations

4.1.1 Ansonia, Connecticut. In 1976 Ansonia constructed a solid waste incineration facility. The following year, in a separate decision, the City installed a spray drier using the flue gases from the furnaces to dry sludge from the wastewater treatment plant. Ansonia's Department of Public Works runs both the wastewater treatment plant and the collection of solid waste. The service area for both of these functions is delineated by the City's boundaries.

While the refuse incinerator was out of service due to an explosion in the shredder, Ansonia took the opportunity to rebuild the air pollution control equipment to meet air pollution standards and to modify the sludge drier. Meanwhile, solid waste was being transported a landfill at a cost of $14 per ton and the sludge was dried in drying beds before being landfilled. The wet scrubber has been replaced and the incinerator is now back on line. However, as no funds were available for repairs and modification needed for the drier, sludge is still landfilled following solar drying.

The solid waste incineration consists of two rocking grate, continuously stoked incinerators with a combined capacity of 200 TPD of MSW. The plant operates on an eight hours per day, five days per week schedule, burning 40 TPD of shredded MSW, which represents about 70 percent of Ansonia's solid waste load. The remainder is primarily bulky refuse which is landfilled.* A combined flow diagram of the wastewater treatment and solid waste disposal operations is shown in Figure 13.

The sewage treatment plant generates 12.5 dry TPD of digested sludge with a 5 percent solids content. When the codisposal system was operating, the sludge was pumped there to be dried in a Nichols spray drier to 85 percent solids. As the drier never reached design capacity, only about half of the sludge was ever dried in it, with the remainder being dried in drying beds. The spray drier will be modified in order to increase its capacity; after modification, the dried sludge will be given away for use as a soil conditioner.

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*Roy F. Weston, Inc., op. cit.

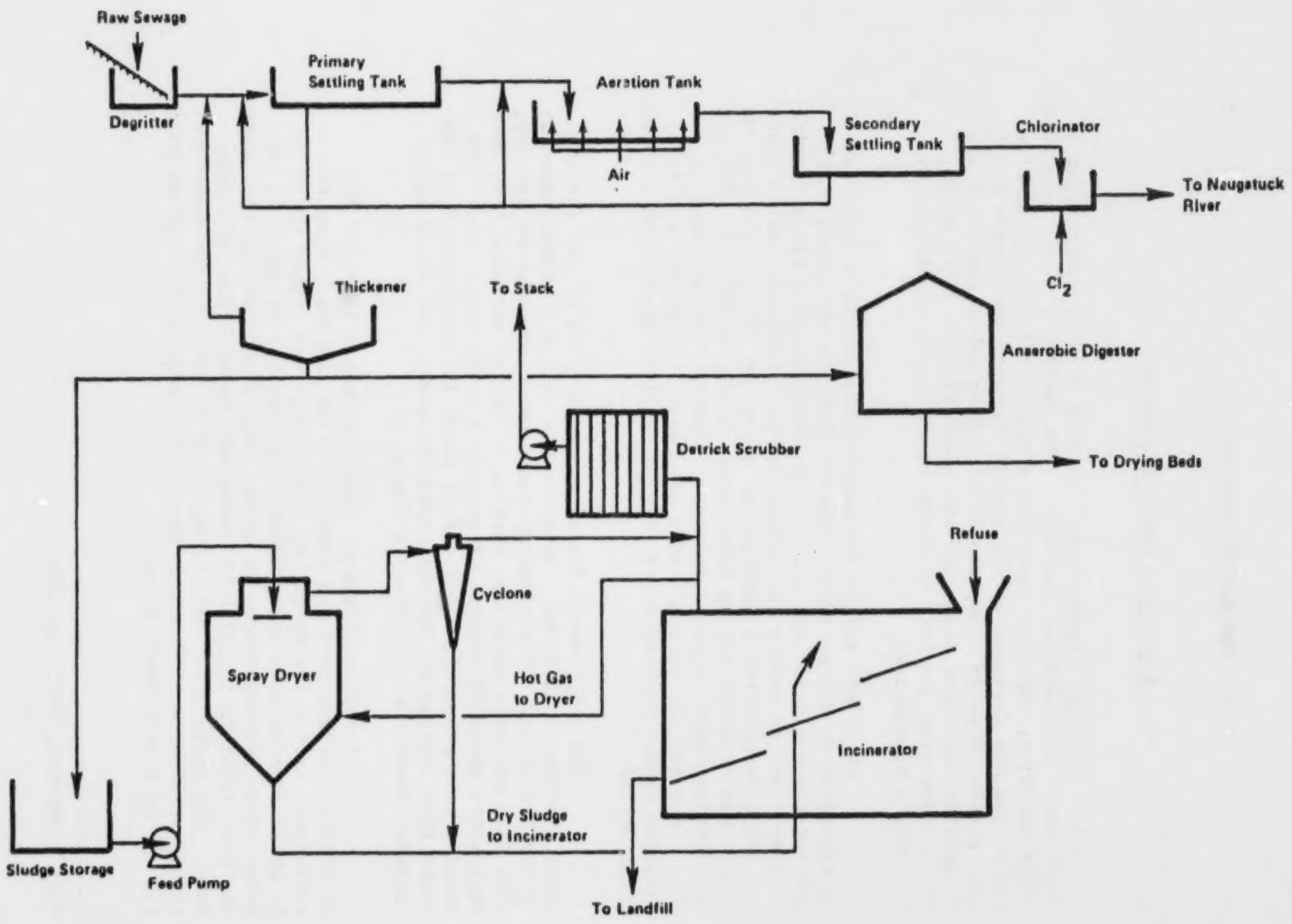
Raw Sewage
Degritter
Primary Settling Tank
Aeration Tank
Air
Secondary Settling Tank
Chlorinator
To Naugatuck River
Cl_2
Thickener
To Stack
Anaerobic Digester
Detrick Scrubber
To Drying Beds
Refuse
Cyclone
Spray Dryer
Hot Gas to Dryer
Incinerator
Dry Sludge to Incinerator
Sludge Storage
Feed Pump
To Landfill

Figure 13. Codisposal process schematic, Ansonia, Connecticut. Source: Roy F. Weston, Inc.

The implementation of the codisposal project at Ansonia was facilitated by having the authority for the disposal of both MSW and MSS lie with the Department of Public Works. As the service areas for these functions are the same, covering only the City of Ansonia, it was not necessary to allocate the operating costs of the project between the wastewater and solid waste users. The economics of landfilling MSW in northeastern communities such as Ansonia are such that incineration is frequently a viable method of disposing of MSW. Sludge drying provides a convenient market for the recovered energy from MSW incineration, and is usually a cost-effective method of sludge disposal.

4.1.2 Central Contra Costa County, California. Planning for the expansion of the Central Contra Costa Sanitary District (CCCSD) sewage treatment plant began in 1970; it was subsequently decided to reclaim the effluent for industrial reuse. A water contract was negotiated with the Central Contra Costa Water District (CCCWD) which will market the water to a nearby oil refinery.

Two things combined to make CCCSD consider codisposal:

- The high lime treatment will result in a relatively inert sludge (30 percent volatile) which would require a large amount of fuel for incineration. CCCSD also plans to recalcinate to recover lime, which is also an intensive operation.
- Natural gas service has been withdrawn, and alternative fuels are prohibitively expensive.

The CCCSD is responsible for wastewater collection and treatment and the disposal of sewage sludge. The service area boundaries for solid waste and sewage collection are shown in Figure 14. The collection of wastewater will be gradually extended to the boundaries of the District when the expansion of the treatment plant is complete.

The authority for the collection and disposal of solid waste was given to CCCSD so that the District could franchise the collection of MSW by private haulers in unincorporated areas of Central Contra Costa County. Collection rates are set by the Cities of Concord, Martinez, Pleasant Hill and Walnut Creek, and by CCCSD in Lafayette and unincorporated areas.

Solid waste from Central Contral Costa County is collected by private haulers and taken to the Acme Fill Corporation's sanitary landfill near Martinez. The tipping fee for

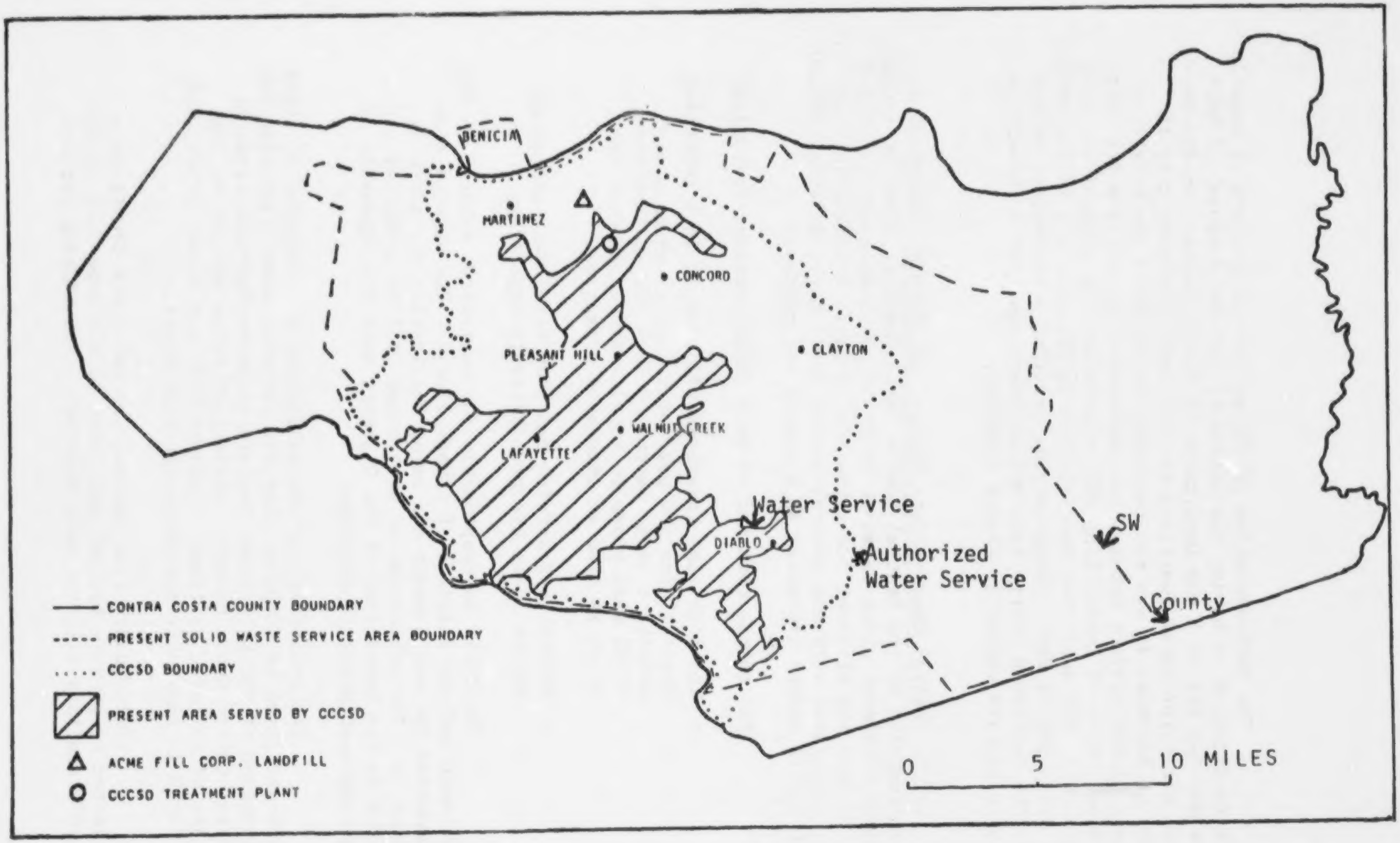
BENICIA
MARTINEZ
CONCORD
PLEASANT HILL
CLAYTON
WALNUT CREEK
LAFAYETTE
DIABLO
Water Service
Authorized Water Service
SW
County
0 5 10 MILES
CONTRA COSTA COUNTY BOUNDARY
PRESENT SOLID WASTE SERVICE AREA BOUNDARY
CCCSD BOUNDARY
PRESENT AREA SERVED BY CCCSD
ACME FILL CORP. LANDFILL
CCCSD TREATMENT PLANT

Figure 14. CCCSD boundary and present service area, and solid waste area service boundary for Acme corporation landfill. Source: Brown and Caldwell, 1974.

MSW at this facility is $0.75 per cubic yard,* which is approximately $2.60 per ton, assuming a density of 290 lbs. per cubic yard. The useful life of this facility is at least 20 years, and possibly 40 years, depending on the amount of waste imported from other parts of Contra Costa County.

The present CCCSD treatment plant has a capacity of 30 MGD which is being increased to 40 MGD. Two sludges will be produced from the centrifugal classification stage in the completed CCCSD plant. One will contain mostly organic solids and will have a 12 to 18 percent solids content, with a heat content of 4300 Btus per pound of dry solids. The second sludge will contain mostly lime solids (66 percent of total solids), and will have a heat content of 1300 Btus per pound of dry solids, at 24 to 30 percent solids. The generation rate of the first sludge is expected to be 35 dry TPD, and 60.5 dry TPD for the second sludge.

In 1976 Brown and Caldwell and the BSP Division of Envirotech Corporation retrofitted a six-hearth multiple hearth furnace (MHF) at the old CCCSD treatment plant to use refuse-derived fuel. Tests run on that unit indicated that pyrolysis (starved air combustion) of an RDF and sludge mixture at a ratio fo 2:1 was technically and economically feasible.

The two existing eleven-hearth MHFs at the CCCSD treatment plant will be retrofitted so that RDF can be fed to hearths number 4 and 5. The top hearth in each furnace will be adapted for use as an afterburner. Two additional ten-hearth MHFs will be constructed with RDF feed ports on hearths number 3 and 5. Two waste heat boilers will be constructed in order to provide steam for the generation of 100 percent of the electricity requirements of the plant. A schematic depiction of this codisposal process is shown in Figure 15.

The design capacity of the proposed solid waste processing facility is 1200 TPD, which is the anticipated MSW generation in 1986. Processing will include primary shredding and air classification after which the light fraction will undergo cyclone separation, screening, and secondary shredding to produce about 605 TPD of RDF. Plans to recover ferrous metals and aluminum have been abandoned.

The construction of the new MHFs and the modifications of the old units to accept RDF will make the plant 100 percent eligible for funding under EPA's Clean Water Act Construction

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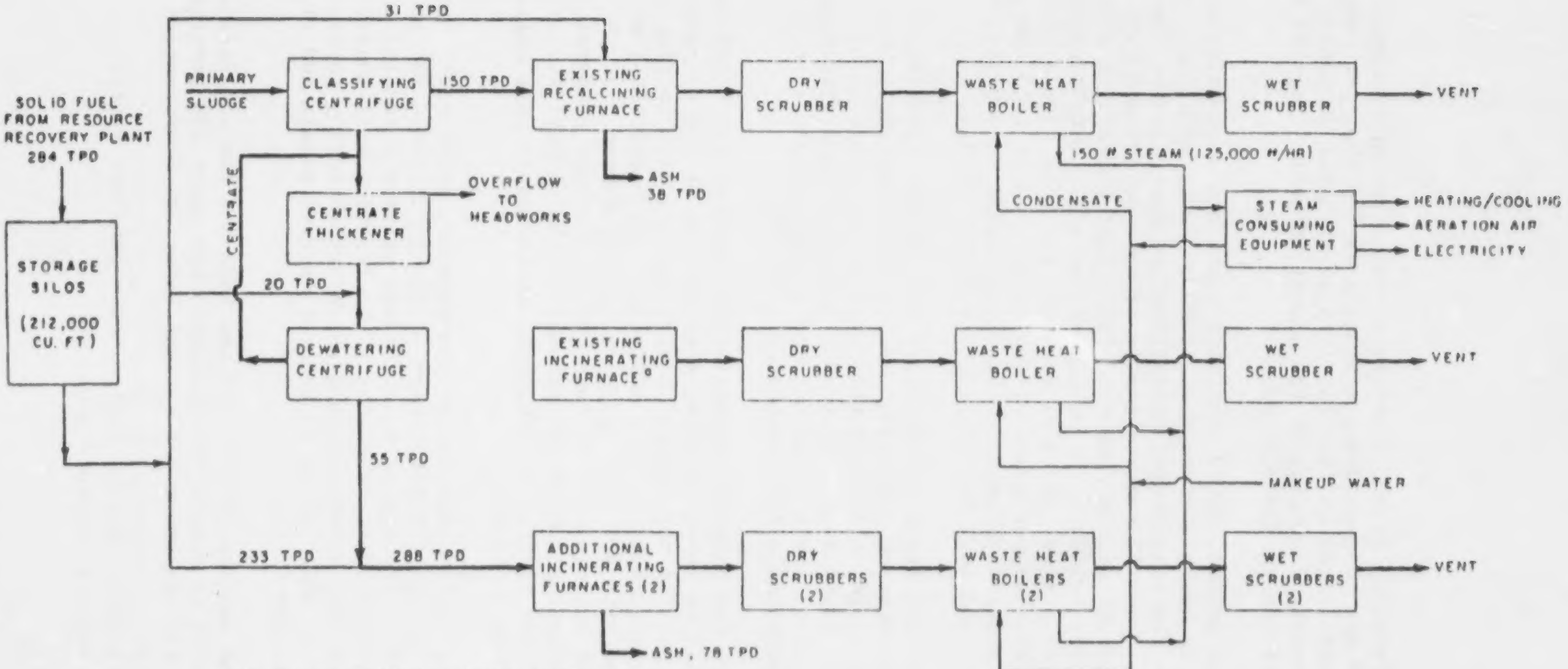
*Brown and Caldwell, Central Contra Costa Sanitary District: solid waste resource recovery study.


SOLID FUEL FROM RESOURCE RECOVERY PLANT 284 TPD
STORAGE SILOS (212,000 CU. FT)
31 TPD
PRIMARY SLUDGE
CLASSIFYING CENTRIFUGE
150 TPD
EXISTING RECALCINING FURNACE
ASH 38 TPD
CENTRATE
CENTRATE THICKENER
OVERFLOW TO HEADWORKS
20 TPD
DEWATERING CENTRIFUGE
55 TPD
233 TPD
288 TPD
EXISTING INCINERATING FURNACE *
ADDITIONAL INCINERATING FURNACES (2)
ASH, 78 TPD
DRY SCRUBBER
DRY SCRUBBER
DRY SCRUBBERS (2)
WASTE HEAT BOILER
WASTE HEAT BOILER
WASTE HEAT BOILERS (2)
150 # STEAM (125,000 #/HR)
CONDENSATE
MAKEUP WATER
WET SCRUBBER
STEAM CONSUMING EQUIPMENT
WET SCRUBBER
WET SCRUBBERS (2)
VENT
HEATING/COOLING
AERATION AIR
ELECTRICITY
VENT
VENT

The existing incinerating furnace serves as backup to other 3 furnaces

Figure 15. Schematic for codisposal process, Central Contra Costa Sanitary District. Source: Brown and Caldwell, 1974.

Grants Program (75 percent federal, 12½ percent state, and 12½ percent local funding). The capital cost associated with generating electricity will be partially eligible (approximately 20 to 30 percent) for Construction Grant Funds. These costs include the waste heat boilers, the solid waste processing facility, and the generators.

CCCSD does not intend to charge a tipping fee for MSW deposited at the resource recovery facility, but it will be able to dispose of its ash and the heavy fraction produced in RDF production at the Acme Fill Corporation site without charge or for a nominal fee only.* The Acme Fill Company is owned by a group of private solid waste collection companies who would be reluctant to lose the revenues from solid waste converted to RDF that would normally be landfilled at their facility. Although CCCSD has the authority to require that MSW be taken to the solid waste processing facility, it chose not to exercise this authority because of political considerations.

The driving force behind the implementation of the CCCSD codisposal project appears to have been the extremely high costs projected for sludge incineration and recalcinating using fossil fuels. The additional costs associated with codisposal will be paid for by the wastewater user, since CCCSD has declined to require that MSW be deposited at the RDF facility for an artificial tipping fee. Presumably, these costs will be offset by the reduced cost of fuel.

4.1.3 Duluth. The Western Lake Superior Sanitary District (WLSSD) was formed in 1971 by enabling legislation passed by the Legislature of the State of Minnesota. Its purpose is to improve and protect the water quality of the St. Louis River and St. Louis Bay, as well as to safeguard other important rural natural resources that lie within the District's boundaries. The first goal of WLSSD was the construction of a regional advanced wastewater plant to replace seven obsolete primary treatment facilities. This plant is under construction in Duluth.

The original design of the WLSSD regional facility called for the incineration of sludge in multiple hearth furnaces. However, after the Oil Embargo of 1973-1974 and the subsequent sharp rise of fuel oil prices, WLSSD examined other fuels to meet its sludge disposal needs. It was found that the codisposal of sludge with MSW would be more cost-effective than the original system. A comparison of the costs for the latter and the best codisposal scheme is shown in Table 19.* When it became clear that MSW could provide the energy for thermal sludge disposal, enabling legislation was passed to specify WLSSD's solid waste powers and responsibilities. WLSSD encompasses portions of two counties, Carlton and St. Louis (see Figure 16), both of which are covered under existing county-wide or regional solid waste management plans. The problem of overlapping responsibilities has been avoided by close cooperation between WLSSD and responsible county departments. The WLSSD anticipates that both Carlton and St. Louis Counties will recognize WLSSD's solid waste plan by formal amendment of their respective county plans to incorporate WLSSD's plans by reference.**

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*John Larson, CCCSD, personal communication.

Municipal solid waste is hauled by private companies to two landfills, the Duluth Disposal Company Sanitary Landfill (DDCSL) and the Carlton County Sanitary Landfill (CCSL). These landfills are located within the WLSSD boundaries, but also serve portions of St. Louis and Carlton Counties outside the boundaries of WLSSD. In 1975 the MSW generation rate in WLSSD was 248 TPD; this figure is expected to increase to 315 TPD by 1984.*** Landfill costs at DDCSL and CCSL are currently about $2.49 to $2.57 per ton of MSW.****

The regional advanced wastewater treatment plant recently constructed by WLSSD in Duluth is expected to generate approximately 68.4 dry TPD of waste activated sludge (WAS) dewatered to 20 percent solids. Also included in this figure are grit and screenings. It is anticipated that the heating value of this sludge will range between 5060 and 5400 Btus per pound of dry solids.

The codisposal technology selected for this project provides for the combustion of a combined RDF/MSS feed in a fluidized-bed furnace (FBF). The RDF will be prepared by coarse shredding, magnetic separation, air classification. The light fraction will be shredded to a maximum size of 1 to 1½ inches

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*Consoer, Townsend & Associates, Solid waste disposal system: preliminary engineering report.

**WLSSD, Solid Waste management plan. 1977 version.

***Consoer, Townsend & Associates, op. cit.

****WLSSD, op. cit.

TABLE 19

COMPARISON OF COSTS FOR ORIGINAL SYSTEM AND SYSTEM WITH COINCINERATION IN FLUIDIZED-BED FURNACE*

	Original System	Coincineration with FBF
	($000)	
Capital Investment	11,165	15,848
Engineering, Legal Fees, etc., at 10%	1,117	1,585
TOTAL	12,282	17,433
Amortization at 6½%, 15 Years	1,307	1,855
Personnel	226	432
Electrical Power	108	285
Process Fuel	1,022	NIL
HVAC Fuel	261	NIL
Maintenance	343	457
Residue Disposal	30	119
Waste Transfer Operation	-	126
Gross Annual Cost	3,297	3,274
Credits		
Disposal Fees at 45¢/Cu. Yd. or $2.57/ton	-	469
Sale of Ferrous Metals[†]	-	69
Net Annual Cost	3,297	2,736

* Source: Consoer, Townsend & Associates.

[†] Priced at $10.00/ton.

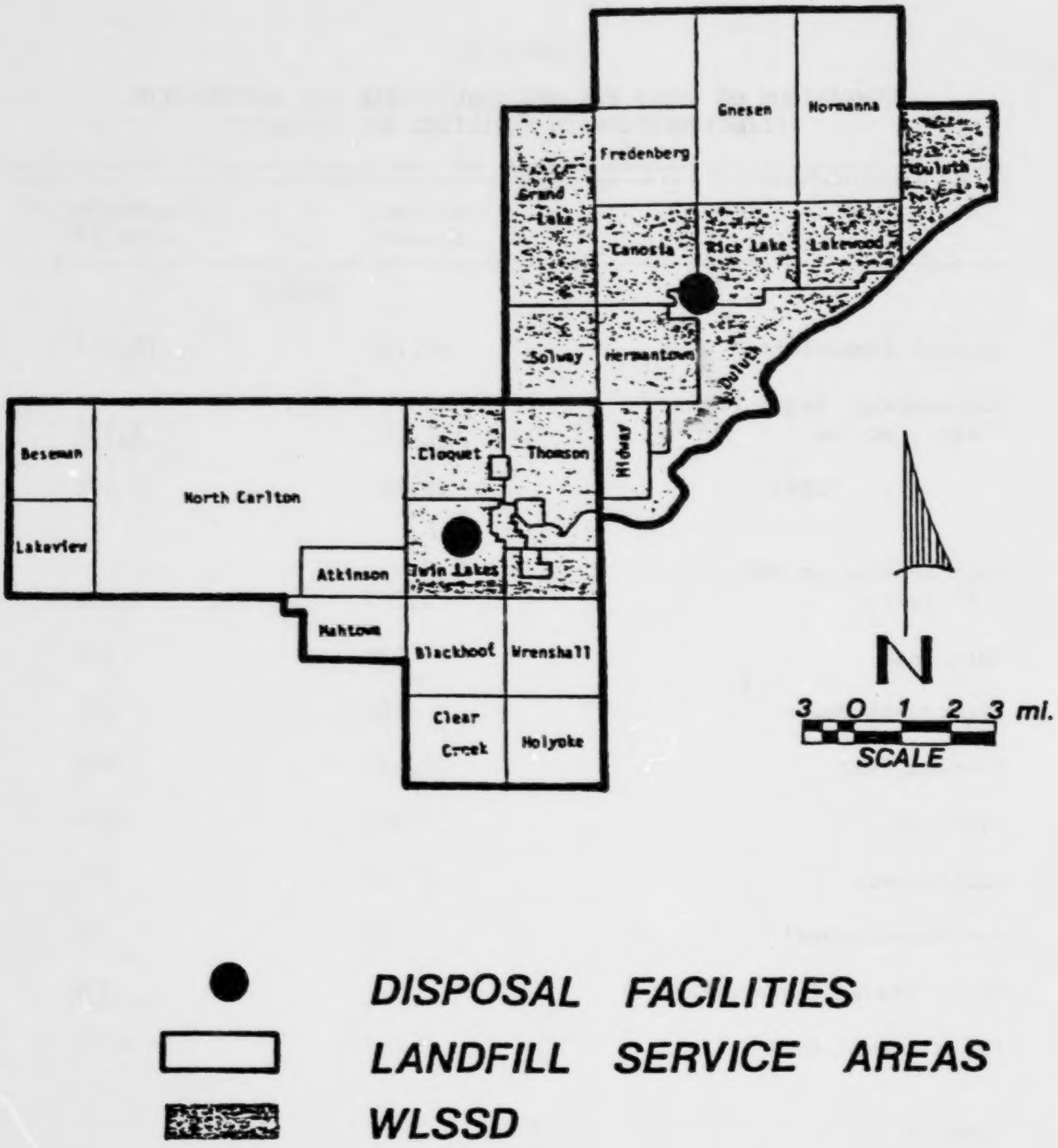
Gnesen
Normanna
Fredenberg
Grand Lake
Duluth
Canosia
Rice Lake
Lakewood
Solway
Hermantown
Duluth
Beseman
North Carlton
Cloquet
Thomson
Midway
Lakeview
Atkinson
Twin Lakes
Mahtown
Blackhoof
Wrenshall
Clear Creek
Holyoke
N
3 0 1 2 3 mi.
SCALE
DISPOSAL FACILITIES
LANDFILL SERVICE AREAS
WLSSD

Figure 16. WLSSD boundaries and service areas for Duluth Disposal Company Sanitary Landfill (DDCSL) and Carlton County Sanitary Landfill. Source: Western Lake Superior Sanitary District.

for use as RDF. A waste heat boiler is used to recover heat from the flue gases; the steam thus generated can be either used within the plant or sold. A potential market for steam is the nearby transit authority building. A schematic of the system is shown in Figure 17. Construction of the codisposal system is complete and is currently undergoing shakedown.

The capacity of the solid waste processing facility (SWPF) is 280 TPD for each of two process trains, although only 160 TPD will be required for the incineration of the sludge. WLSSD hopes eventually to operate the SWPF at near capacity if a market for the additional RDF can be found. Meanwhile, the excess MSW will be landfilled at the CCSL.

The 1974 enabling legislation prohibits WLSSD from using revenues from the operation of disposal facilities (i.e., tipping fees) to fund the operation of the wastewater treatment facilities. The intent of this legislation was to prevent the residents of Carlton and St. Louis Counties who will not be served by the WLSSD wastewater treatment plant from being assessed for part of the facilities' costs through increased tipping fees at WLSSD disposal facilities. Consequently, the solid waste tipping fee will include the capital, operating and maintenance costs for only the scale, tipping floor, primary shredder, and ferrous metals separation at the SWPF. The solid waste user also receives the credits from the sale of recovered ferrous metals. The remaining costs associated with the SWPF are to be allocated to the wastewater user. The tipping fee has tentatively been set at $3.10 per ton.*

The Federal Government is funding 75 percent of the capital costs for both the regional advanced wastewater treatment plant and the SWPF under EPA's Construction Grants Program. State funds are providing a further 15 percent, with the remaining 10 percent to be financed locally through the sale of General Obligation bonds. EPA's allowance of 75 percent funding eligibility for the entire capital costs (including the SWPF) occurred prior to the issuance of any formal Federal policy concerning codisposal projects. In the future, funding will be provided according to a specific multi-purpose allocation formula.

The ability of WLSSD to gain control of the municipal solid waste stream through the 1974 enabling legislation played a major role in the successful implementation of the project. It prevented a situation where WLSSD would have to compete with a privately run landfill (DDCSL) for MSW, and has allowed WLSSD to levy a tipping fee of $3.10 per ton at the SWPF which is $0.50 to $0.60 per ton greater than prevailing landfill costs. The

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*Minutes of WLSSD Board Meeting, October 25, 1977.

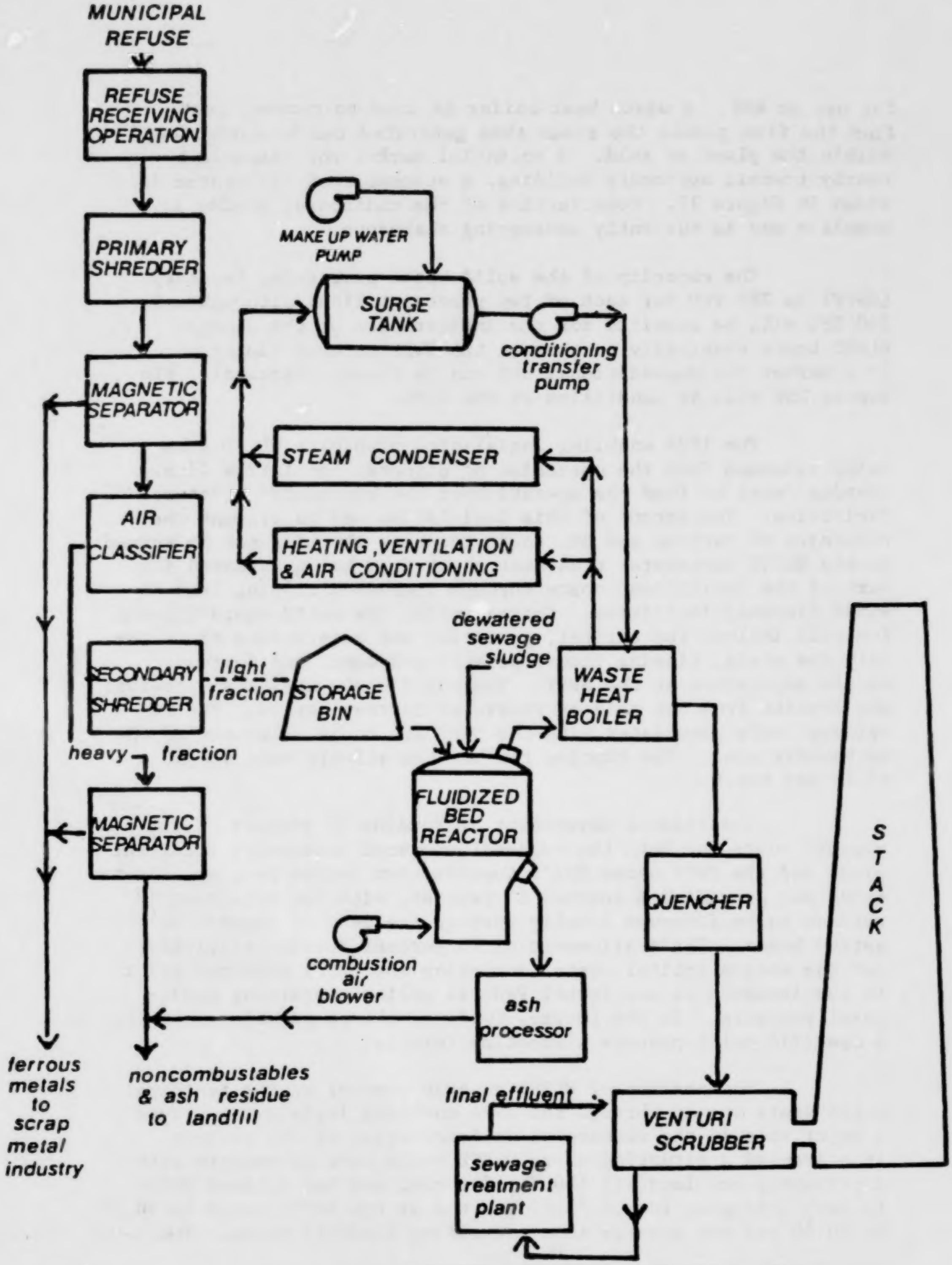
MUNICIPAL REFUSE
REFUSE RECEIVING OPERATION
PRIMARY SHREDDER
MAGNETIC SEPARATOR
AIR CLASSIFIER
SECONDARY SHREDDER
light fraction
heavy fraction
STORAGE BIN
MAGNETIC SEPARATOR
MAKE UP WATER PUMP
SURGE TANK
conditioning transfer pump
STEAM CONDENSER
HEATING, VENTILATION & AIR CONDITIONING
dewatered sewage sludge
WASTE HEAT BOILER
FLUIDIZED BED REACTOR
combustion air blower
ash processor
QUENCHER
STACK
final effluent
VENTURI SCRUBBER
sewage treatment plant
ferrous metals to scrap metal industry
noncombustables & ash residue to landfill

Figure 17. **Process schematic for Western Lake Superior Sanitary District Coincineration Facility.**

justification for the higher fee is that DDCSL does not comply with environmental standards and the tipping fee would have to have been increased to pay for the required modifications. A second reason for success was the approval of full construction Grants funding for the SWPF capital costs. These factors greatly increased the economic attractiveness of the project to WLSSD.

4.1.4 Glen Cove, New York. The City of Glen Cove (population 27,000 is currently dumping its sewage sludge in the ocean and hauling its MSW to the New Jersey Meadowlands for landfilling. With the EPA ban on ocean dumping after 1981 and New Jersey's efforts to prevent the disposal of out-of-state solid waste at their landfills, the City was forced to examine alternative disposal options for both sludge and MSW.*

The City examined three systems:

- co-burning of MSW and MSS and generation of electric power for the wastewater treatment plant and incinerator complex,
- a sludge burning incinerator at the wastewater treatment plant and an independent refuse disposal facility, and
- sludge disposal at a proposed Nassau County regional sludge disposal facility and refuse disposal at the existing Hempstead incineration facility.

The first of these alternatives was considered to be the most cost-effective and is being implemented by the City.

The City of Glen Cove controls both the collection of MSW and the operation of the wastewater treatment plant through the Department of Public Works. The City currently collects 125 TPD of MSW and pays a private company $22 per ton to haul it to landfill sites in New Jersey. The existing 4 MGD treatment plant generates 3.5 dry TPD of sludge at 20 percent solids which is barged to the Atlantic Ocean for disposal. An 8 MGD activated sludge nitrification treatment plant is under construction and will produce 5 dry TPD of sludge also at 20 percent solids.

In the codisposal phase of the project, a thin layer of sludge will be placed on the surface of the MSW being fed to a conventional mass-burning incinerator. A waste heat boiler will produce steam which will generate all of the treatment plant's electricity by means of a 2.2 megawatt multi-stage condensing turbine generator set.** A schematic rendering of the codisposal process and a cross-section of the incinerator are shown in Figure 18.

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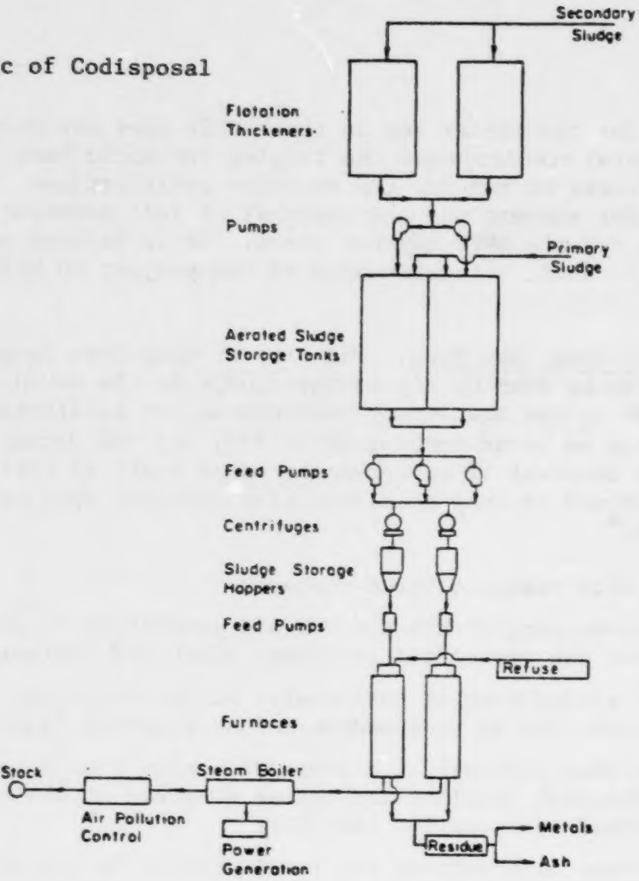
* William F. Cosulich, Co-burning of sludge and refuse and waste heat recovery

** William F. Cosulich, op. cit.

a) Schematic of Codisposal Process


Secondary Sludge
Flotation Thickeners
Pumps
Primary Sludge
Aerated Sludge Storage Tanks
Feed Pumps
Centrifuges
Sludge Storage Hoppers
Feed Pumps
Refuse
Furnaces
Stack
Steam Boiler
Air Pollution Control
Power Generation
Residue
Metals
Ash

b) Cross-Section of Incinerator Building

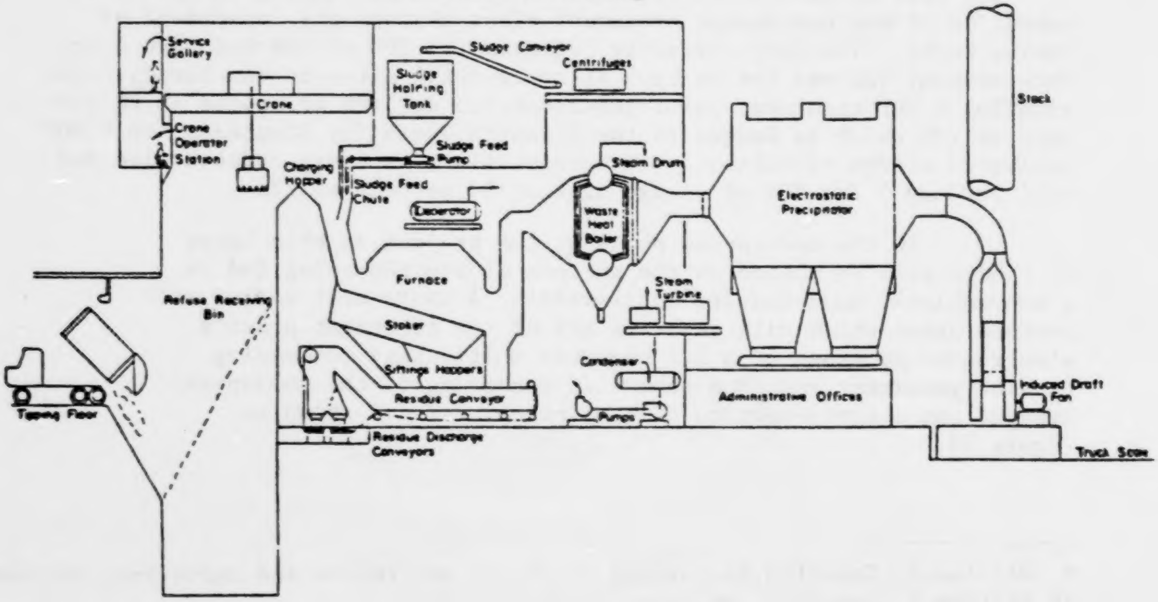

Service Gallery
Crane
Crane Operator Station
Sludge Conveyor
Centrifuges
Sludge Holding Tank
Sludge Feed Pump
Charging Hopper
Sludge Feed Chute
Deaerator
Steam Drum
Waste Heat Boiler
Electrostatic Precipitator
Stack
Furnace
Refuse Receiving Bin
Stoker
Siftings Hoppers
Residue Conveyor
Residue Discharge Conveyors
Tipping Floor
Steam Turbine
Condenser
Pumps
Administrative Offices
Induced Draft Fan
Truck Scale

Figure 18. The Glen Cove codisposal facility. Source: William F. Cosulich Associates.

The Glen Cove facility will consume 175 TPD of MSW plus the 5 TPD of MSS produced by the treatment plant. Since only 125 TPD of MSW are generated within the Glen Cove city limits, 50 TPD will have to be imported from nearby communities. Glen Cove will have to compete for MSW with the energy recovery facility located in the Town of Hempstead. Since Glen Cove is closer to the communities involved, city officials are confident that a tipping fee of $12 per ton (vs. $16 to $18/ton at Hempstead) will be low enough to attract adequate supplies of MSW.*

Construction Crant Funds will be available for approximately 50 percent of the entire Glen Cove wastewater treatment and solid waste incineration complex. The wastewater treatment plant, up to the centrifuges, is 100 percent eligible for Construction Grants Funds, and the furnaces are partially eligible. The energy recovery aspects of the project (waste heat boilers, generators, etc.) are ineligible.

The idential service areas for sewage treatment and MSW collection, the consolidation of these activities, and the ultimate disposal of MSW and MSS under the authority of one city department (Public Works) undoubtedly have greatly facilitated the implementation of codisposal in Glen Cove. The need to allocate operating costs between the solid waste and wastewater users is minimized, and the centralization of authority minimizes the problems of coordinating actions regarding MSW and MSS disposal.

Another factor that favored the adoption of codisposal in Glen Cove was the fact that it became necessary to find alternative disposal systems for both MSS and MSW at about the same time when the City was planning to construct a new wastewater treatment plant. Thus, Glen Cove was not irreversibly committed to a disposal alternative for either MSS or MSW and could consider a combined disposal option.

4.1.5. Harrisburg, Pennsylvania. The Harrisburg refuse incinerator was completed in 1972, and it was subsequently decided to use it for the disposal of sewage sludge as well. Digested sludge has been combusted at the facility by adding it directly to the furnace feed hopper. A sludge drying facility using steam generated by the refuse incinerator is under construction and is scheduled for completion by late 1979.

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*Ernest Pascucci, Public Works Director, City of Glen Cove, N.Y., personal communication.

The authority for the collection and disposal of MSW is exercised by the Department of Public Works for all solid waste generated within the City limits of Harrisburg. The City requires that all MSW be dumped at the incinerator. Private refuse haulers bring MSW from suburban communities to the incinerator and are levied a tipping fee of $10.80, $11.80 or $12.80 per ton, depending on the bulk density of the waste. Many suburban haulers find it more economical to use these facilities than to haul their loads for greater distances to transfer stations or landfills, where the tipping fees are $7.00 to $7.50 and $5.00 to $6.00, respectively.

The 31 MGD capacity wastewater treatment plant is operated bt the Department of Public Works in Harrisburg, but is owned by the Harrisburg Sewage Authority which also is responsible for financing the facility. The service area of the treatment plant includes Harrisburg and six suburban communities. The cost of treatment is shared on the basis of sewage flow contributed to the system.

The wastewater treatment process produces primary sludge and a waste activated sludge conditioned with aluminum sulfate. The combined sludge will be pumped to the dewatering facility where it will be dewatered to 22 percent solids by vacuum filtration and then dried to 85 percent solids using steam. This product may be marketed as a mulch/soil conditioner or burned in the incinerator. It is anticipated that about two-thirds of the energy used in drying the sludge can be recovered from the combustion of the dried product. The Harrisburg Sewerage Authority will buy steam from the incinerator for sludge drying and pay an additional fee to dispose of the dried sludge at the incinerator.

The Harrisburg incinerator consists of two waterwall furnaces with a design capacity of 720 TPD, although it normally operates seven days per week and consumes 400 TPD of MSW. Metals are separated from the MSW after hammermilling and shredding the bulky materials, and also from the residue after combustion using magnetic separators. It is hoped that the residue can be recovered for use in road construction as road base aggregate and asphalt.

The dewatering facility and the equipment that will deliver the dried sludge to the furnace feed hopper will be 100 percent eligible for funding under the Construction Grants Program.

The chances of success for a codisposal project are greatly enhanced in a situation as Harrisburg's, where the viability of refuse incineration has been demonstrated. Institutional problems can be greatly reduced by selecting a technology that requires no commonly-owned equipment. This allows the capital and operating costs incurred by the sludge and solid waste components of the codisposal project to be clearly defined. This was achieved in Harrisburg by having a separate sludge dewatering facility whose only connections with the incinerator will be pipe for incoming steam and a means of conveying the dried sludge to the feed hopper at the incinerator. These will also be the points of economic transfer between the wastewater treatment plant (Harrisburg Sewerage Authority) and the incinerator (Harrisburg Department of Public Works), as the former will pay for steam and the disposal of dried sludge. The advantage of this arrangement is that it results in a mutually beneficial economic relationship between the two institutional entities, rather than a partnership where some equitable method must be found to allocate the costs and/or benefits to the partners.

4.1.6 Minneapolis - St. Paul, Minnesota. The Metropolitan Waste Control Commission (MWCC) is in the process of expanding the Metropolitan Wastewater Treatment Plant (Metro Plant) from 219 MGD to 290 MGD. The sludge disposal system must be desinged to handle the associated increase in sludge generation from 288 TPD to 390 TPD. At the time of design the Metro Plan was experiencing increasing interruption of its natural gas supply, which, when combined with the rise in the price of oil, led to the careful consideration of codisposal.

In 1975 the MWCC proposed the construction of sludge disposal facilities for the copyrolysis of sludge and refuse. An independent evaluation of this system found that it was not the most cost-effective alternative and raised questions as to whether a dependable supply of MSW could be secured.* MSWW subsequently abandoned the copyrolysis project in favor of a system that will incinerate heat dried sludge in MHFs, recoverying energy using waste heat boilers. Flue gases from the MHFs will be used to dry the sludge in two rotary driers.**

The authority for the collection and treatment of wastewater in the Twin Cities Metropolitan ARea (TCMA) is held by the Metropolitan Council (MC). Representatives from the seven counties in the TCMA sit on the MC. This body determines the boundaries of the sewage service area and determines the long-term development of

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*Camp Dresser & Mc Kee, Inc., Evaluation of Proposed Sludge Disposal Facilites with Pyrolysis of Sludge/Refuse - Metropolitan Wastewater Treatment Plant.

**Sludge, (11): September 19, 1978.

MWCC. The MWCC is composed of commissioners from the communities in the MWCC service area, and is concerned with the operation of its wastewater treatment facilities. MWCC operates two treatment plants, the Metro Plant (219 MGD) in St. Paul and the Severa Plant (24 MGD) in Burnsville, which receive sewage from Minneapolis and St. Paul and their suburbs within about a 20 mile radius. MWCC currently incinerates 288 TPD of sludge in MHFs at the Metro Plant using fuel oil only when natural gas supplies are interrupted. Natural gas service has been discontinued.

In creating the MWCC, the Minnesota Legislature intended that this body should eventually acquire authority over the collection and disposal of MSW; however, this authority has not been transferred from the counties. Solid waste is collected by the City of Minneapolis and by private haulers in St. Paul and suburban areas. St. Paul and some suburban communities do not have mandatory refuse collection.

Municipal solid waste is currently hauled to sanitary landfills (there were ten operating within 30 miles of the Metro Plant in 1975) (see Figure 19). Tipping fees ranged from $2.20 to $4.00 per ton at these facilities in 1975.

The codisposal system under consideration called for the copyrolysis of some of the sludge with solid waste to produce a pyrogas to be used in the incineration of the remainder of the sludge in MHFs. Heat was to be recovered from these furnaces by a waste heat boiler producing steam to be used in the sludge driers. The char produced in the pyrolyzer was also to be recovered and used as a fuel. A schematic rendering of the proposed system is shown in Figure 20.

The RDF was to be prepared by primary shredding, primary air classification, secondary shredding and secondary air classification. Ferrous metals and aluminum were also to be recovered from the heavy fraction. The design capacity of the processing plant was 360 TPD. A depiction of the proposed solid waste processing system is shown in Figure 21.

Since MWCC does not have control over the municipal waste stream, the allocation of costs between the system's solid waste and wastewater users would have occurred through the tipping fee. This fee would have had to be low enough to attract MSW on a competitive basis. MWCC calculated that a tipping fee of $6 to $8 at the Metro Plant would be more attractive option than hauling MSW to outlying landfills for many communities in the center of the TCMA.

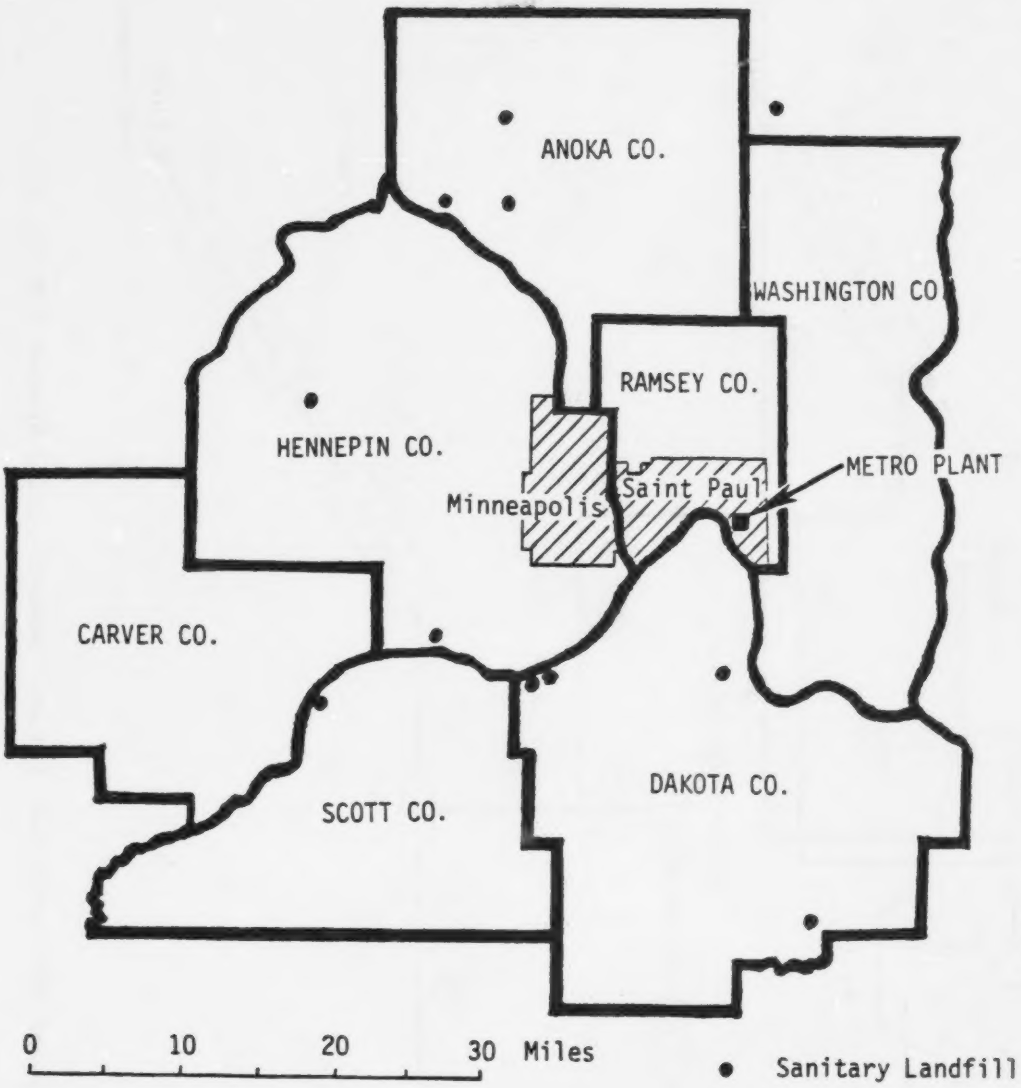
ANOKA CO.
WASHINGTON CO.
RAMSEY CO.
HENNEPIN CO.
Minneapolis
Saint Paul
METRO PLANT
CARVER CO.
DAKOTA CO.
SCOTT CO.
0
10
20
30 Miles
● Sanitary Landfill

Figure 19. Map of Twin Cities Metropolitan Area (TCMA) showing location of metro plant and landfill sites. Source: Camp, Dresser & McKee, Inc.

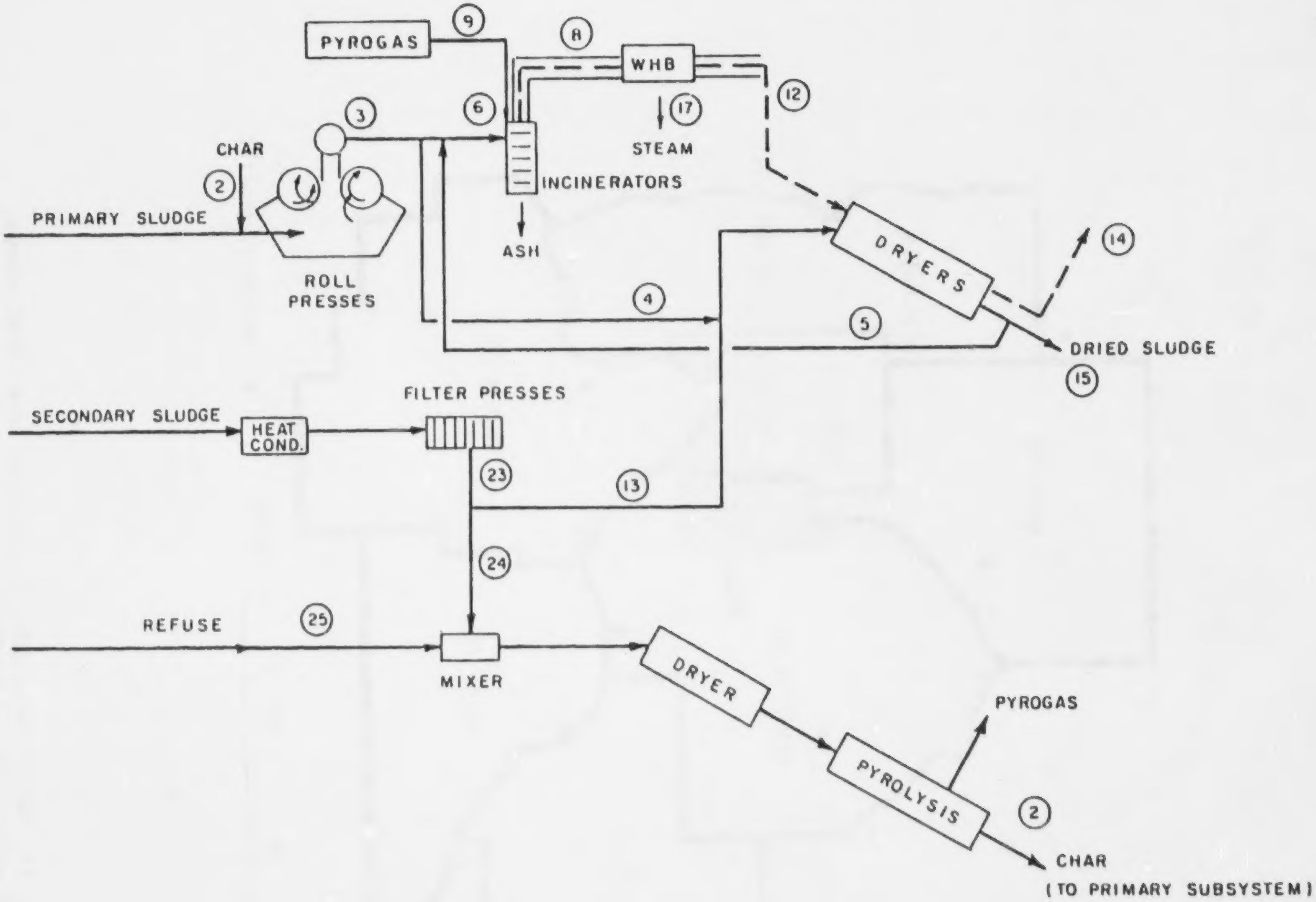
PYROGAS
⑨
⑧
WHB
⑫
③
⑥
⑰
STEAM
CHAR
②
INCINERATORS
PRIMARY SLUDGE
ROLL PRESSES
ASH
DRYERS
⑭
④
⑤
DRIED SLUDGE
⑮
FILTER PRESSES
SECONDARY SLUDGE
HEAT COND.
㉓
⑬
㉔
REFUSE
㉕
MIXER
DRYER
PYROGAS
PYROLYSIS
②
CHAR
(TO PRIMARY SUBSYSTEM)

Figure 20. Proposed MWCC codisposal system. Source: Camp, Dresser & McKee, Inc.

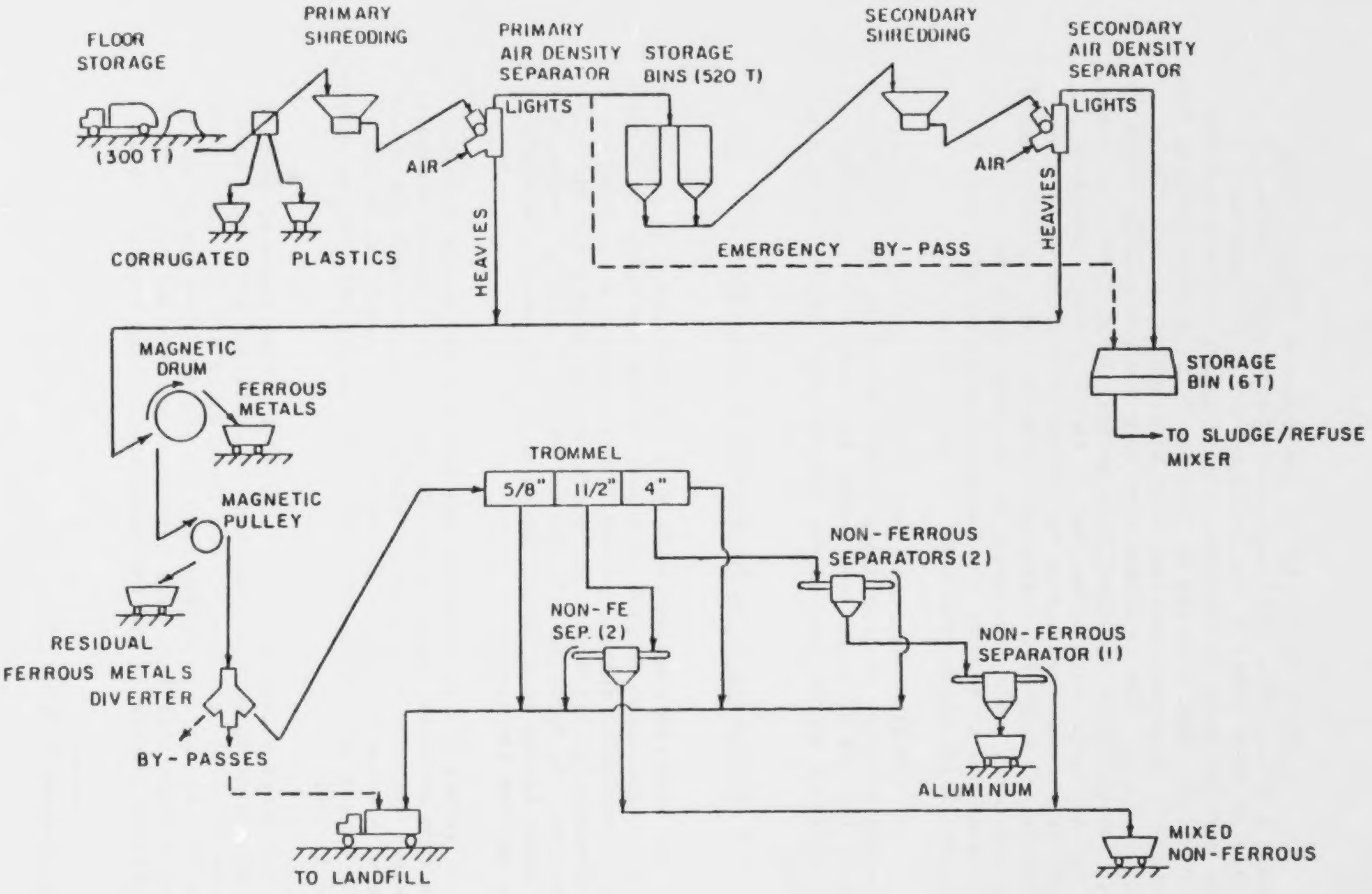
FLOOR STORAGE
(300 T)
PRIMARY SHREDDING
CORRUGATED
PLASTICS
PRIMARY AIR DENSITY SEPARATOR
LIGHTS
AIR
HEAVIES
STORAGE BINS (520 T)
SECONDARY SHREDDING
SECONDARY AIR DENSITY SEPARATOR
LIGHTS
AIR
HEAVIES
EMERGENCY BY-PASS
STORAGE BIN (6T)
TO SLUDGE/REFUSE MIXER
MAGNETIC DRUM
FERROUS METALS
MAGNETIC PULLEY
RESIDUAL FERROUS METALS DIVERTER
BY-PASSES
TROMMEL
5/8"
11/2"
4"
NON-FERROUS SEPARATORS (2)
NON-FE SEP. (2)
NON-FERROUS SEPARATOR (1)
ALUMINUM
TO LANDFILL
MIXED NON-FERROUS

Figure 21. Proposed MWCC solid waste processing system. Source: Camp, Dresser & McKee, Inc.

In their evaluation of the proposed project, Camp Dresser & McKee, Inc. (CDM) expressed conern about the availability of solid waste.* Two waste-to-energy projects were under consideration at the time, one in Hennepin County and the second in St, Paul proposed by Phoenix, Inc., a trash hauling firm which has a five-year contract with Minneapolis to haul MSW to landfill sites. CDM concluded that when non-processable solid waste (construction and demolition wastes, inert materials, trees, fly ash and slag, auto hulks, etc.), the 25 percent reduction in MSW generation that occurs in the winter and the waste generated beyond a 30-mile radius of the Metro Plant are substracted from the total waste generation in the TCMA, there may not be sufficient MSW to support the two-waste-to-energy projects, let alone the Metro Plant codisposal scheme (see Table 20).

CDM also concluded that both the capital and annual operating costs of the codisposal system would be significantly greater for the proposed codisposal system than for a system that directly incinerates sludge and recovers energy for sludge drying.

4.2 Codisposal as an Alternative to Ocean Dumping

For seaboard communities on both the East and West coasts of the U.S., the ocean dumping of sewage sludge and other waste products (demolition debris, refuse, dredge spoils, etc.) has been an economically attractive and operationally simple disposal alternative. It involves only the collection and barge transport of liquid sludge to a designated point at sea, where the sludge load is then discharged.

In recent years, attention has been focused on the hazards that this procedure poses to marine life as well as the aesthetic problmes that can be created as sludge migrates toward the shoreline with ocean currents. Consequently, a federal ban on all ocean dumping activities has been implented and will become effective in 1981.

For those cities which currently ocean dump their sludges, a new sludge management program must be developed and implemented before the 1981 deadline. Since these cites are in a unique position of being able to design disposal systems from the ground up, it is assumed that they have greater incentives and opportunites to utilize innovative systems/technologies than any other U.S.

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*Camp Dresser & McKee, Inc., op. cit.

TABLE 20

AVAILABILITY OF PROCESSABLE MSW IN TWIN CITIES METROPOLITAN AREA (TCMA) FOR THE PROPOSED CODISPOSAL FACILITY AT THE METRO PLANT*

	Tons Per Week
Average MSW generation	72,500
Non-processable	-33,500
MSW beyond 30 miles	-1,500
25 percent winter reduction in MSW generation	-9,000
Waste recycled	-5,000
Availability of processable MSW	23,500
Waste required by Phoenix Inc. facility	12,000
Waste required by Hennepin Co. facility	13,000
	25,000

* Source: Camp, Dresser & McKee, Inc.

community. Therefore, the seven* major ocean dumping municipalities were investigated to identify the status of their wastewater management planning and to assess their interest in codisposal as a sludge management option. However, in most cases, the institutional impediments to its implementation are sufficiently great so as to preclude it as a viable option within the 1981 timeframe. Therefore, a number of these cities have either eliminated codisposal from consideration, or have elected to implement an interim sludge disposal system, while planning to re-evaluate codisposal along with alternatives at a later date. Table 21 summarizes the status of planning activities with the ocean dumping communities (for specific details, See Appendix C).

The major concern of the ocean dumping communities at this time is to ensure that a practical, reliable alternative sludge disposal system can be implemented before the 1981 ban. While all of the communities contacted have expressed a philosophical commitment to innovative systems such as codisposal, they are unwilling to risk the possibility that the resolution of institutional problems, particularly establishing the authority to control wastes and a program of joint management, could delay codisposal's implementation beyond the 1981 timeframe. This is particularly true for those communities in which the current method of solid waste disposal is landfilling. In these cases, a new solid waste management system would have to be developed, as well as a sludge management system, before more sophisticated codisposal options like coincineration are possible. As a result, many of the ocean dumping communities have reserved codisposal systems for consideration in their "second stage" planning efforts, while settling on an "interim" sludge disposal plan (usually composting) which can be implemented within the designated timeframe, and which will allow them time for more careful consideration of the other options.

Cost is also mentioned as an area of concern by these communities. While the cost of coincinerating solid waste with sewage sludge may not significantly exceed that of sludge incineration, the cost of processing the solid waste prior to incineration can be considerable, especially for those communities which currently landfill their solid waste at little cost. In addition, several communities reported that uncertainties over federal and state funding policies disposed them toward single purpose alternatives.

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*The seven waste management agencies contacted are responsible for about 92 percent of the total sludge quantity permitted for ocean dumping on the East coast.

TABLE 21

SUMMARY OF 201 PLANNING STATUS IN OCEAN DUMPING COMMUNITIES

Major Ocean Dumping Communities	Actual Quantity Dumped (Wet Tons) (1976)	Status of 201 Planning Report	Recommended Sludge Management Alternative	Comments
Bergen Co. Sewer Authority	246,000	Not Yet Completed	Interim: Composting Long Term: Codisposal	Would like to implement the Union Carbide Purox System as a long term disposal alternative.
Linden Roselle-Rahway Sewer Authority	228,000	Not Yet Completed	Composting	Has recently begun to consider coincineration of sludge and solid waste in modular combustion units, utilizing low-termperature pyrolysis.
Middlesex County Sewer Authority	300,000	Completed	Incineration in MHFs	Codisposal not recommended because of: - Institutional problems (obtaining authority, allocating costs, etc.) - Cost (solid waste currently landfilled at $3/ton).
Passaic Valley Sewer Commission	579,000	Not Yet Completed		Looking at several codisposal options, which would be preferred "if economics work out." Worried about Clean Air Act. Not enough land to compost, so will be forced into some other alternative.

TABLE 21

SUMMARY OF 201 PLANNING STATUS IN OCEAN DUMPING COMMUNITIES
(Con't)

Major Ocean Dumping Communities	Actual Quantity Dumped (Wet Tons) (1976)	Status of 201 Planning Report	Recommended Sludge Management Alternative	Comments
Nassau County Department of Public Works	401,000	Complete	Not Yet Finalized	Conducting pilot studies on composting, codisposal, landfilling. Codisposal (Black Clawson) preferred. Participation in the Hempstead or Glen Gove projects also being considered.
Westchester County Department of Environmental Facilities	138,000	Interim Report Complete	Composting (Being Re-evaluated)	Coincineration eliminated due to anticipated air quality problems. Present solid waste disposal plans are for resource recovery through steam generation (project stalled).
New York City Department of Water Resources	2,152,000	Not Yet Completed	Interim: Composting Long Term: Not Yet Decided	Opportunities are being identified for coincineration of sludge in existing and planned combustion units, such as refuse incinerators and utility boilers. To date, the extent of interest has not been determined.

Unlike most communities in the U,S,, however, the ocean dumping communities in general seem to be well suited for the implementation of codisposal systems. The communities are predominantly large, producing in excess of 200 dry tons of sludge per day. Thus, they would be able to benefit from the economies of scale inherent in capital intensive sludge processes, including codisposal. Further, these cites are all located in a densely populated geographic area along the Eastern seaboard, making the large scale land disposal of sludge and solid waste difficult, if not impossible, for all of them over the long run. Sludge incineration would appear to be a more appropriate disposal alternative, which would likely make codisposal increasingly competitive over time. Until codisposal's intitutional problems are resolved, however, it is likely that the ocean dumping communities will continue to pursue single-purpose sludge and solid waste management programs.

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APPENDIX A. MUNICIPAL SOLID WASTE ECONOMIC DATA*

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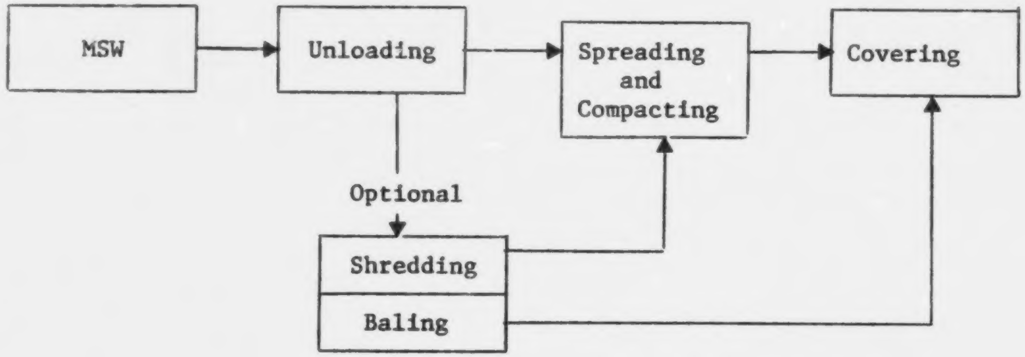
* All source references cited in the following tables may be found at the end of this appendix.

TABLE A-1

LANDFILLING*


MSW
Unloading
Spreading and Compacting
Covering
Optional
Shredding
Baling

- System Economics based on Sources and Assumptions shown below:

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton Materials Energy	Avg.-Revenue/Ton Materials Energy	Avg. Net Cost/Ton
2,400-4,800	1.50-20.00	6.00	NA	NA	6.00

- Gordian Estimate for 3 facility sizes

TPD	Capital (x 1000)	Annual Cost -- $/Ton			Revenue -- $/Ton Materials Energy	Net Cost -- $/Ton
		Capital	O&M	Total		
100	385	1.76	6.24	8.00	NA	8.00
400	1,185	1.32	4.68	6.00	NA	6.00
1000	2.400	1.10	3.90	5.00	NA	5.00

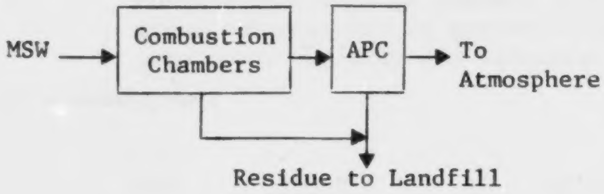
- Assumptions:
  Capital is determined as 22% of total annual cost; capital amortization is at 7% over 10 years.

*Source: 1, 2, 3.

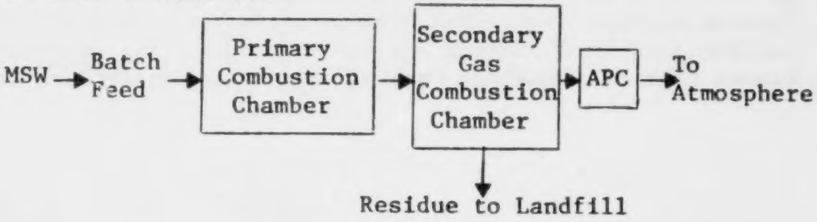
TABLE A-2

REFRACTORY WALL INCINERATION/MODULAR INCINERATOR

Refractory Wall


MSW
Combustion Chambers
APC
To Atmosphere
Residue to Landfill

Modular Incinerator


MSW
Batch Feed
Primary Combustion Chamber
Secondary Gas Combustion Chamber
APC
To Atmosphere
Residue to Landfill

- **System Economics based on Sources and Assumptions shown below:**

Range Capital/TPD	**Range-Annual Cost/Ton**	**Avg.-Annual Cost/Ton**	**Range-Revenue/Ton**		**Avg.-Revenue/Ton**		**Avg. Net Cost/Ton**
			Materials	**Energy**	**Materials**	**Energy**	
Refractory Wall							
7,000-25,000	8.00-15.00	12.50	NA		NA		12.60
Modular Incinerator							
12,000-24,000	8.00-18.00	12.00	NA		NA		12.00

- Gordian Estimate for 3 facility sizes

  - Refractory Wall

TPD	Capital (Thousands)	Annual Cost -- $.Ton		
		Capital	O&M	Net $/Ton
100	1,500	4.60	10.40	15.00
400	3,200	2.50	9.50	12.00
1000	6.500	2.00	8.00	10.00

  - Modular Incinerator

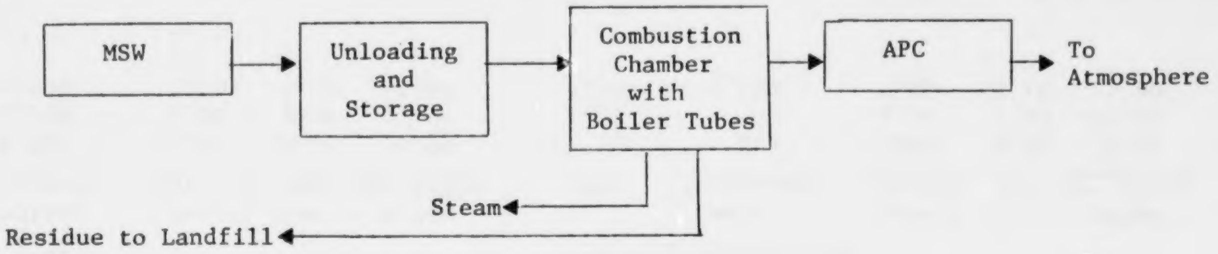
TPD	Capital (Thousands)	Annual Cost -- $/Ton		
		Capital	O&M	Net $/Ton
10	225	7.00	9.00	16.00
50	750	4.50	7.50	12.00
100	1,250	3.85	5.15	9.00

- Assumptions:
  Capital amortized over 20 years at 7%. Resource recovery is not considered as part of these systems.

* Source: 8, 20, 21.

TABLE A-3

RESOURCE RECOVERY - WATERWALL INCINERATION*



- System Economics based on Sources and Assumptions shown below:

Range Capital/TPD	Range-Annual Cost/Ton	Avg. Annual Cost/Ton	Range-Revenue/Ton		Avg.-Revenue/Ton		Avg. Net Cost/Ton
			Materials	Energy	Materials	Energy	
20,000-51,500	13.00-38.00	25.00	NA	7.00-30.00 (steam)	NA	18.00	7.00

- Gordian Estimate for 3 facility sizes

TPD	Capital (x 1000)	Annual Cost -- $/Ton			Revenue -- $/Ton		Net Cost -- $/Ton
		Capital	O&M	Total	Materials	Energy	
250	12,000	15.00	16.00	31.00	NA	18.00	13.00
400	17,000	13.25	15.75	29.00	NA	18.00	11.00
1000	37,000	9.65	15.35	25.00	NA	18.00	7.00

- Assumptions:

Both front and back end materials recovery is possible with this system. However, in this report front end recovery is discussed in the dedicated boiler section and the marketing of back end recovered materials is assumed to be too speculative to consider it as a measurable revenue source. Capital is amortized over 20 years at 7%. Average steam revenues are based on $3.00/1000 lbs. of steam and assuming no efficiency variation among differing boiler sizes.

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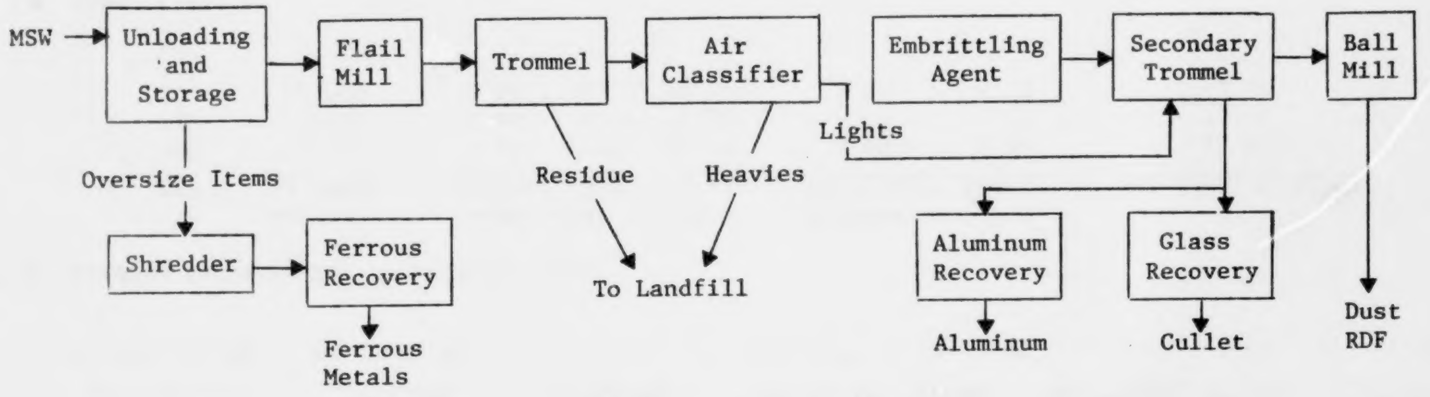
* Source: 1, 4, 8, 9, 10.

TABLE A-4

RESOURCE RECOVERY - RDF (DUST)


MSW
Unloading and Storage
Flail Mill
Trommel
Air Classifier
Embrittling Agent
Secondary Trommel
Ball Mill
Lights
Oversize Items
Residue
Heavies
Shredder
Ferrous Recovery
To Landfill
Aluminum Recovery
Glass Recovery
Ferrous Metals
Aluminum
Cullet
Dust RDF

- System Economics based on Sources and Assumptions shown below:

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton Materials	Range-Revenue/Ton Energy	Avg.-Revenue/Ton Materials	Avg.-Revenue/Ton Energy	Avg. Net Cost/Ton
21,600-23,625	18.00	18.00	.90-5.80	5.50-16	3.40	7.00	7.60

- Gordian Estimate for 3 facility sizes

TPD	Capital (x 1000)	Annual Cost -- $/Ton Capital	Annual Cost -- $/Ton O&M	Annual Cost -- $/Ton Total	Revenue -- $/Ton Materials	Revenue -- $/Ton Energy	Net Cost -- $/Ton
250	7,500	9.25	14.75	24.00	3.40	7.00	13.60
400	10,000	7.70	13.30	21.00	3.40	7.00	10.60
1000	22,600	7.00	11.00	18.00	3.40	7.00	7.60

- Assumptions:

  Average materials revenue assumes $25/ton ferrous at 7% of waste stream with 90% recovery; $200/ton aluminum at .07% of waste steam with 60% recovery; $15/ton glass at 9% of waste steam with 70% recovery. RDF value is based on 7500 Btus/lb. at 80% efficient conversion rate (on a Btus per incoming lb. basis) compared to coal at $1.00/million Btus with a 12% handling cost subtracted.

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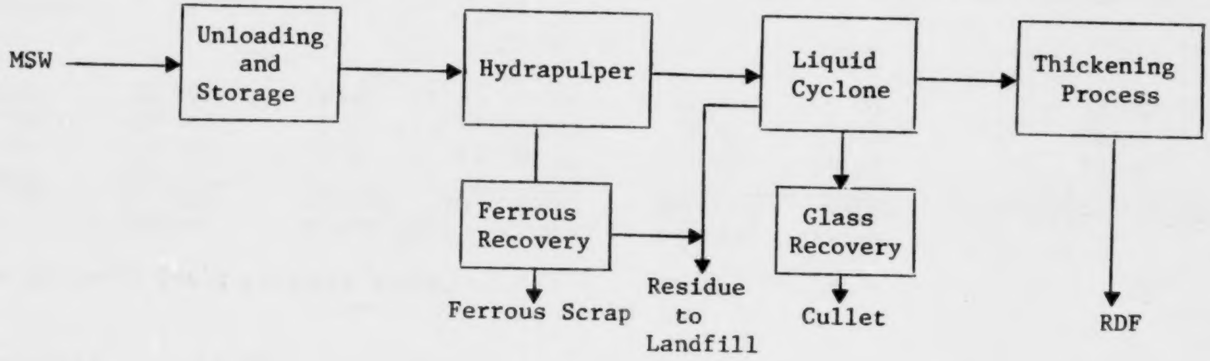
* Source: 1, 3, 10, 6, 15.

TABLE A-5

RESOURCE RECOVERY - RDF (WET)*


MSW
Unloading and Storage
Hydrapulper
Liquid Cyclone
Thickening Process
Ferrous Recovery
Glass Recovery
Ferrous Scrap
Residue to Landfill
Cullet
RDF

- System Economics based on Sources and Assumptions shown below:

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton Materials	Range-Revenue/Ton Energy	Avg.-Revenue/Ton Materials	Avg.-Revenue/Ton Energy	Avg. Net Cost/Ton
16,000-20,000	18.00-25.00	20.00	.90-5.80	3.00-10.50	3.40	5.00	12.50

- Gordian Estimate for 3 facility sizes

TPD	Capital (x 1000)	Annual Cost -- $/Ton Capital	Annual Cost -- $/Ton O&M	Annual Cost -- $/Ton Total	Revenue -- $/Ton Materials	Revenue -- $/Ton Energy	Net Cost -- $/Ton
250	5,000	6.15	17.85	24.00	3.40	5.00	15.60
400	7,000	5.40	16.60	22.00	3.40	5.00	13.60
1000	16,000	4.90	15.10	20.00	3.40	5.00	11.60

- Assumptions:

  Materials assumptions are the same (as for previous dust RDF system) for all recovery processes. RDF revenues are based on process efficiency of 70% for converting Btus/lb. incoming MSW to Btus/lb. of RDF compared to $1.00/million Btu price for coal less 30% handling charge.

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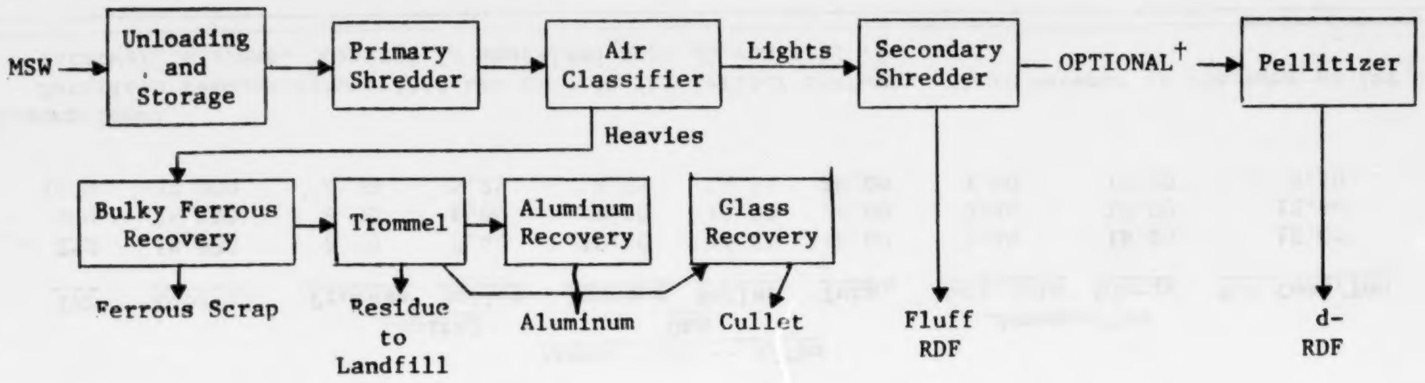
*Source: 1, 3, 11, 5.

TABLE A-6

RESOURCE RECOVERY - RDF (FLUFF, DENSIFIED)*


MSW
Unloading and Storage
Primary Shredder
Air Classifier
Lights
Secondary Shredder
OPTIONAL†
Pellitizer
Heavies
Bulky Ferrous Recovery
Trommel
Aluminum Recovery
Glass Recovery
Ferrous Scrap
Residue to Landfill
Aluminum
Cullet
Fluff RDF
d-RDF

- **System Economics based on Sources and Assumptions shown below:**

Range	Range-Annual	Avg.-Annual	Range-Revenue/Ton		Avg.-Revenue/Ton		Avg. Net
Capital/TPD	Cost/Ton	Cost/Ton	Materials	Energy	Materials	Energy	Cost/Ton
7,000-32,000	12.00-22.50	17.00	.90-5.80	0-10.50	3.40	4.50	9.00

- **Gordian Estimate for 3 facility sizes**

	Capital	Annual Cost -- $/Ton			Revenue -- $/Ton		
TPD	(x 1000)	Capital	O&M	Total	Materials	Energy	Net Cost -- $/Ton
250	6,750	8.25	13.75	22.00	3.40	4.60	14.00
400	8,800	6.75	13.25	20.00	3.40	4.60	12.00
1000	17,000	5.25	11.75	17.00	3.40	4.60	9.00

- **Assumptions:**

  Capital is amortized over years at 7%. Materials revenue is same as previous processes. RDF revenue is calculated on basis of 70% process efficiency in Btu/lb. conversion from imout. MSW to RDF, compared to $1/million Btu, price of coal less 30% handling charge.

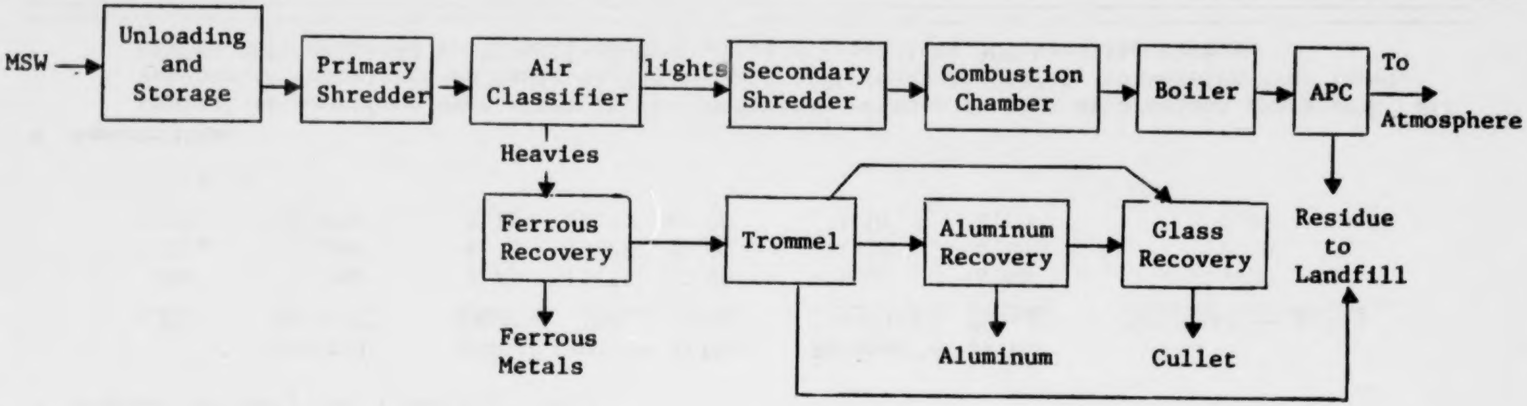
---

*Source: 1, 2, 3, 4, 5, 6, 11, 15, 16.

†Densifying or pelletizing adds an average of $4/input ton to gross costs. RDF revenue is worth around $2/input ton more due to decreased handling charges for a net increase of $2 per ton.

TABLE A-7

RESOURCE RECOVERY - DEDICATED BOILER


MSW
Unloading and Storage
Primary Shredder
Air Classifier
lights
Secondary Shredder
Combustion Chamber
Boiler
APC
To Atmosphere
Heavies
Ferrous Recovery
Ferrous Metals
Trommel
Aluminum Recovery
Aluminum
Glass Recovery
Cullet
Residue to Landfill

- **System Economics based on Sources and Assumptions shown below:**

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton Materials	Range-Revenue/Ton Energy	Avg.-Revenue/Ton Materials	Avg.-Revenue/Ton Energy	Avg. Net Cost/Ton
24,000-48,000	18.00-40.00	31.00	.90-5.80	7.00-25.00	3.40	18.00	9.60

- Gordian Estimate for 3 facility sizes

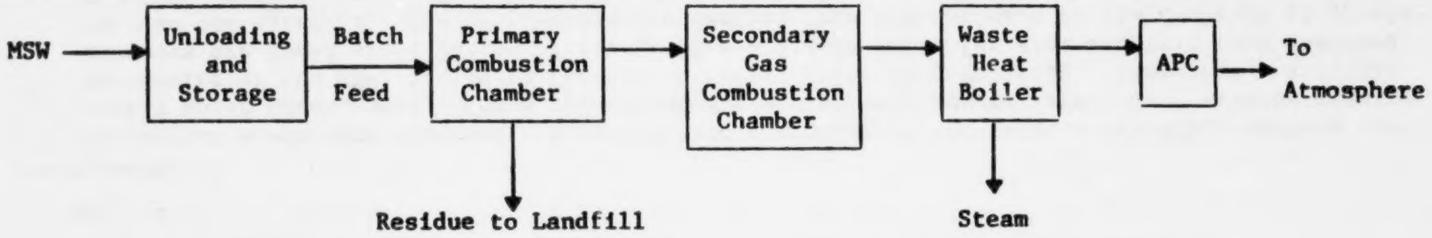
		Annual Cost -- $/Ton							
		Capital		O&M			Revenue/Ton		
TPD	Capital	Process	Boiler	Process	Boiler	Total	Materials	Energy	Net Cost/Ton
250	13,000	8.60	7.40	10.40	14.60	40.00	3.40	18.00	18.60
400	16,750	6.90	6.00	9.10	12.00	34.00	3.40	18.00	12.60
1000	32,000	4.60	5.25	8.40	11.75	30.00	3.40	18.00	8.60

- Assumptions:
  Materials revenue assumptions are same as for earlier systems. Steam revenue is the same as for Waterwall systems. Capital is amortized over 20 years at 7%.

* Source: 1, 4, 9, 10, 6, 5.

TABLE A-8

RESOURCE RECOVERY - MODULAR INCINERATOR*


MSW
Unloading and Storage
Batch Feed
Primary Combustion Chamber
Residue to Landfill
Secondary Gas Combustion Chamber
Waste Heat Boiler
Steam
APC
To Atmosphere

- **System Economics based on Sources and Assumptions shown below:**

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton		Avg.-Revenue/Ton		Avg. Net Cost/Ton
			Materials	Energy	Materials	Energy	
20,000-30,000	12.00-22.00	15.50	NA	6-15.00	NA	9.00	6.50

- **Gordian Estimate for 3 facility sizes**

TPD	Capital (x 1000)	Annual Cost -- $/Ton			Revenue -- $/Ton		Net Cost -- $/Ton
		Capital	O&M	Total	Materials	Energy	
10	360	11.00	9.50	20.50	NA	9.00	11.50
50	1,250	7.50	9.00	16.50	NA	9.00	7.50
100	2,000	6.00	8.00	14.00	NA	9.00	5.00

- **Assumptions:**

  Materials recovery is possible with this system, but as it is not a common practice it is not considered here. Revenues from steam sales are based on boiler efficiencies capable of producing 4000 lbs. of low pressure steam per ton/input waste with sales pegged to $3/thousand lbs. with an average 25% incentive discount. Capital is amortized over 20 years at 7%.

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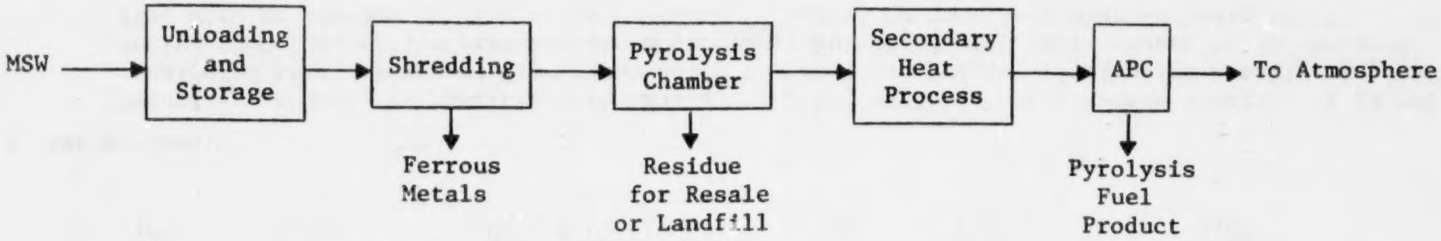
* Source: 5, 13, 16.

TABLE A-9

RESOURCE RECOVERY - PYROLYSIS*


MSW
Unloading and Storage
Shredding
Pyrolysis Chamber
Secondary Heat Process
APC
To Atmosphere
Ferrous Metals
Residue for Resale or Landfill
Pyrolysis Fuel Product

- **System Economics based on Sources and Assumptions shown below:**

Range Capital/TPD	Range-Annual Cost/Ton	Avg.-Annual Cost/Ton	Range-Revenue/Ton		Avg.-Revenue/Ton		Avg. Net Cost/Ton
			Materials	Energy	Materials	Energy	
20,000-50,000	15.00-40.00	24.00	0-3.00	5.00-19.00	2.00	9.00	13.00

- **Gordian Estimate for 3 facility sizes**

TPD	Capital (x 1000)	Annual Cost -- $/Ton			Revenue -- $/Ton		Net Cost -- $/Ton
		Capital	O&M	Total	Materials	Energy	
250	12,500	15.50	16.50	32.00	1.70	9.00	21.30
400	16,000	12.25	15.75	28.00	1.70	9.00	17.30
1000	33,600	10.25	13.75	24.00	1.70	9.00	13.30

- **Assumptions:**

  The system shown here represents a generalized composite of the various pyrolysis systems currently under development. Costs and revenues are similarly generalized. Most systems require processing of the MSW, including ferrous recovery, prior to pyrolizing. Therefore, materials revenues are based on $1.50/ton of metals plus a $1/ton value for slag and frit type residues as road bed material. Energy revenues are derived from EPA estimate of Btu contents of pyrolysis fuel products (gas, oil) compared to current market prices of the corresponding fossil fuel ($1.60/mil Btu-gas, $2.40/mil Btu-oil) less a 10% handling charge. Capital has been amortized over 20 years at 7%.

---

* Source: 1, 3, 4, 6, 7, 11, 12.

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APPENDIX B. MUNICIPAL SEWAGE SLUDGE ECONOMIC DATA

Methodology. Cost estimates for various representative sludge processing trains were developed by aggregating the costs for each unit process within the train. A summary of these cost estimates is displayed in Table B-1. Tables B-2 through B-13 display the total estimated capital and operating costs and relevant assumptions for each of the unit processes. These unit costs are aggregated into process trains in Tables B-14 through B-23, in order to derive an estimated cost per ton of dry solids for each of the various processing options. Specific assumptions relating to adjustments or deviations resulting from the aggregation of the unit costs are also presented in Tables B-14 through B-23.

Primary reliance was placed upon cost curves developed by Consoer, Townsend & Associates in their report for Nassau County, New York facilities planning. The estimates reflect November 1977 costs in the New York area, and are based on the following assumptions:

- Operation and maintenance costs, unless otherwise specified, include labor, power, materials and chemical costs.
- Power costs are estimated at $0.05 per kWh.
- Labor costs are estimated to be $8.35 per hour, including fringe benefits.
- Fuel oil and gasoline are estimated at $0.37 per gallon and $0.60 per gallon, respectively.
- Chemical costs of $0.02 per lb. for lime and $0.10 per lb. for ferric chloride were assumed.
- Construction costs are based upon an ENR index of 3108.
- Capital costs are amortized over 20 years at 7 percent interest.
- Level of reliability of the estimates equals ± 30 percent.

TABLE B-1

SUMMARY OF SLUDGE DISPOSAL COSTS*,†

Disposal Alternatives	Capital Costs ($ x 10^3)			Annual Operating Costs ($ x 10^3)			Total Cost ($/Ton)			Revenue Potential ($/Ton)	Net Cost ($/Ton)		
	10 TPD	50 TPD	100 TPD	10 TPD	50 TPD	100 TPD	10 TPD	50 TPD	100 TPD		10 TPD	50 TPD	100 TPD
OPTION 1:													
A	3,250	10,000	18,500	730	2,781	5,118	200	153	140	-	200	153	140
B	5,105	11,050	16,350	839	2,821	4,765	230	155	131	-	230	155	131
OPTION 2:													
A	4,500	11,800	19,500	747	2,412	4,295	205	132	117	-	205	132	117
B	6,355	12,850	17,350	876	2,556	4,151	240	140	113	-	240	140	113
OPTION 3:													
A	4,500	13,200	24,500	836	2,688	4,995	230	148	137	-	230	148	137
B	6,355	14,250	22,350	1,045	3,232	5,451	265	156	133	-	265	156	133
OPTION 4:	2,019	6,570	12,700	586	2,001	3,713	161	113	101	-	161	113	101
OPTION 5:	2,020	6,370	11,600	485	1,673	2,794	133	92	76	-	133	92	76
OPTION 6:	3,066	9,666	16,633	716	2,834	5,198	198	156	144	20	178	136	124
OPTION 7:	1,210	4,500	9,200	460	1,705	2,978	126	94	81	-	126	94	81

* Source: Gordian Associates Incorporated.

† All values are stated as 1978 dollars per dry ton of solids.

TABLE B-2

UNIT PROCESS ECONOMICS - VACUUM FILTRATION

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	850	76	200	276	756	75.60
50	3000	270	800	1070	2932	58.64
100	6000	540	1250	1790	4904	49.04

Assumptions:

- Capital costs include pumps, internal piping and electrical controls, mechanical equipment, conveyors, sludge-cake storage hopper, and buildings.
- Operating costs include costs of chemical conditioning, chemical costs of $0.10/lb for $FeCl_3$ and $0.02/lb for CaO. $FeCl_3$ additions @ 25% by weight, CaO @ 10% by weight.

---

* Source: Consoer, Townsend & Associates

TABLE B-3

UNIT PROCESS ECONOMICS - MULTIPLE HEARTH INCINERATION (SLUDGE SOLIDS @ 20%)*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	2400	216	238	454	1243	124.00
50	7000	630	1081	1711	4687	93.74
100	12,500	1125	2203	3328	9118	91.18

Assumptions:

- Dewatering in vacuum filter to 20% solids prior to incineration is assumed but not included in cost estimates.
- Sludge contains 10,000 Btus per lb. dry solids, 75% volatile solids.
- Two units are used for 100% standby at average operating conditions.
- Maintenance and supplies estimated to be 6% of major equipment costs.
- Ash equals 30% of total dry solids by weight and costs $15/ton for hauling and disposal.

---

* Source: Consoer, Townsend & Associates
and Gordian Assoicates Incorporated.

TABLE B-4

UNIT PROCESSING ECONOMICS - FILTER PRESS*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs (\$ x 10^3)	Annual Costs (\$ x 10^3) Capital	Operating	Total	Cost Per Day (\$)	Cost Per Ton Dry Solids (\$)
10	2100	189	180	369	1011	101.10
50	4800	432	650	1082	2964	59.30
100	7000	630	1100	1730	4739	47.39

Assumptions:

- Capital costs include filter presses, pressure pumps, conveyor equipment, sludge storage tanks, and buildings.
- Operating costs include cost of chemical conditioning. Chemical additions for $FeCl_3$@ 2.5% by weight, CaO @ 10% by weight, for raw sludge. Chemical costs of \$0.10/lb for $FeCl_3$ and \$0.02/^{3}lb. for CaO.
- Filter press results in sludge solids content of 35%.

---

* Source: Consoer, Townsend & Associates

TABLE B-5

UNIT PROCESS ECONOMICS - MULTIPLE HEARTH INCINERATION (SLUDGE SOLIDS @ 35%)*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3) Capital	Operating	Total	Cost Per Day ($)	Cost Per Ton Dry Solids ($)
10	2400	216	162	378	1036	103.60
50	7000	630	700	1330	3644	72.88
100	12,500	1125	1440	2565	7027	70.27

Assumptions:

- Dewatering in filter presses to 35% solids prior to incineration is assumed but not included in cost estimates.
- Sludge contains 10,000 Btus per lb. dry solids, 75% volatile solids.
- Two units are used for 100% standby at average operating conditions.
- Maintenance and supplies estimated to be 6% of major equipment costs.
- Ash equals 30% of total dry solids by weight and costs $15/ton for hauling and disposal.

---

* Source: Consoer, Townsend & Associates
and Gordian Associates Incorporated

TABLE B-6

UNIT PROCESSING ECONOMICS - FLUIDIZED BED INCINERATION (SLUDGE SOLIDS @ 20%)*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	4255	382	181	563	1542	154.00
50	8050	724	1027	1751	4797	96.00
100	10,350	931	2044	2975	8150	82.00

Assumptions:

- Dewatering in vacuum filter to 20% solids prior to incineration is assumed but not included in cost estimates.
- Sludge contains 10,000 Btus per lb. dry solids, 75% volatile solids.
- Two units are used for 100% standby at average operating conditions.
- Waste heat used as combustion air pre-heat.
- Maintenance and supplies estimated to be 6% of major equipment costs.
- Ash equals 30% of total dry solids by weight and costs $15/ton for hauling and disposal.

---

* Source: Consoer, Townsend & Associates
and Gordian Associates Incorporated

TABLE B-7

UNIT PROCESSING ECONOMICS - FLUIDIZED BED INCINERATION (SLUDGE SOLIDS @ 35%)*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3) Capital	Operating	Total	Cost Per Day ($)	Cost Per Ton Dry Solids ($)
10	4255	382	125	507	1389	138.90
50	8050	724	750	1474	4038	81.00
100	10,350	931	1490	2421	6632	66.32

Assumptions:

- Dewatering in filter process to 35% solids prior to incineration is assumed but not included in cost estimates.
- Sludge contains 10,000 Btus per lb. of dry solids, 75% volatile solids.
- Waste heat used as combustion air pre-heat.
- Maintenance and supplies estimated to be 6% of major equipment costs.
- Ash equals 30% of total dry solids by weight and costs $15/ton for hauling and disposal.

---

* Source: Consoer, Townsend & Associates
and Gordian Associates Incorporated

TABLE B-8

UNIT PROCESSING ECONOMICS - THERMAL CONDITIONING*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	1250	112	150	262	719	71.90
50	3200	288	400	688	1885	37.70
100	6000	540	700	1240	3397	33.97

Assumptions:

- Capital costs include: sludge feed pumps, grinders, heat exchangers, reactors, boilers, gas separators, and buildings.

---

* Source: Consoer, Townsend & Associates

TABLE B-9

UNIT PROCESSING ECONOMICS - AEROBIC DIGESTION*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	999	90	125	215	588	58.80
50	3200	288	440	728	1994	40.00
100	6200	558	950	1508	4131	41.31

Assumptions:

- Capital costs include basins (20 day detention time) and floating mechanical aerators.
- Mixing requirements: 134 hp/mg
- Oxygen requirements: 1.6 lbs O_2/lb VSS destroyed.

---

* Source: Consoer, Townsend & Associates

TABLE B-10

UNIT PROCESSING ECONOMICS - ANAEROBIC DIGESTION (TWO STAGE)*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	1000	90	24	114	312	31.20
50	3000	270	70	340	932	18.64
100	5100	459	130	589	1613	16.13

Assumptions:

- Capital costs include digestor, heat exchanger, gas collection equipment, control building.
- Feed to digestors is combined primary/WAS and is thickened.
- Feed - 1,900 lb/mg. at 4% solids (75% volatile)
- Loading rate of 0.16 lb/cu. ft./day.
- Operating temperature of 85-110^{0}F.
- Credit is taken for using digestor gas for heating.

---

* Source: Consoer, Townsend & Associates

TABLE B-11

UNIT PROCESSING ECONOMICS - LANDFILLING*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	170	15	80	95	260	26.00
50	370	33	230	263	720	14
100	500	45	370	415	1136	11.36

Assumptions:

- Construction costs include site preparation, front end loaders, monitoring wells, fencing and leachate collection and treatment.
- Operating and maintenance costs are based on landfilling digested biological sludge at 20% solids.
- Costs do not include land purchase or lease, or costs to transport the dewatered sludge.

---

* Source: Consoer, Townsend & Associates

TABLE B-12

UNIT PROCESS ECONOMICS - HEAT DRYING*

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3) Capital	Operating	Total	Cost Per Day ($)	Cost Per Ton Dry Solids ($)
10	966	87	260	347	950	95
50	4866	438	1314	1752	4800	95
100	9633	867	2601	3468	9501	95

Assumptions:

- Dewatering in vacuum filters prior to drying is assumed but not included in cost estimate.
- Maintenance and supplies are estimated to be 6% of major equipment costs.
- Potential economies of scale are not included, due to data limitations.

---

* Source: Consoer, Townsend & Associates

TABLE B-13

UNIT PROCESSING ECONOMICS - COMPOSTING *

Costs:

Capacity (Tons Per Day Dry Solids)	Total Capital Costs ($ x 10^3)	Annual Costs ($ x 10^3)			Cost Per Day ($)	Cost Per Ton Dry Solids ($)
		Capital	Operating	Total		
10	360	32	152	184	504	50.4
50	1500	135	500	635	1740	34.8
100	3200	288	900	1188	3254	32.5

Assumptions:

- Sludge cake solids content at 20%.
- Capital costs include site construction, but do not include land.
- Capital costs amortized over 20 years at 7%.

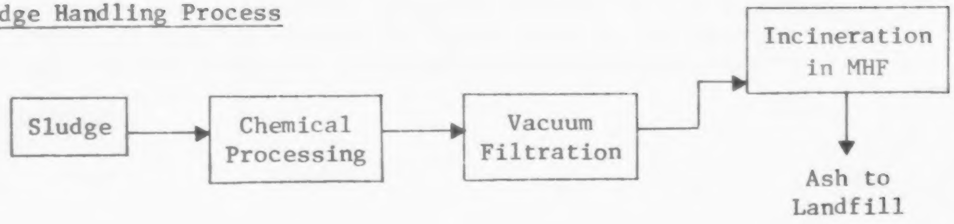
---

* Source: Consoer, Townsend & Associates

TABLE B-14

OPTION 1-A*

Sludge Handling Process


Sludge
Chemical Processing
Vacuum Filtration
Incineration in MHF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Cost ($/Ton Dry Solids)
10	†	76	124	200
50	†	59	94	153
100	†	49	91	140

Assumptions:

- Ash disposal costs are included in incineration costs.
- Vacuum filtration results in sludge cake of 20% solids.

---

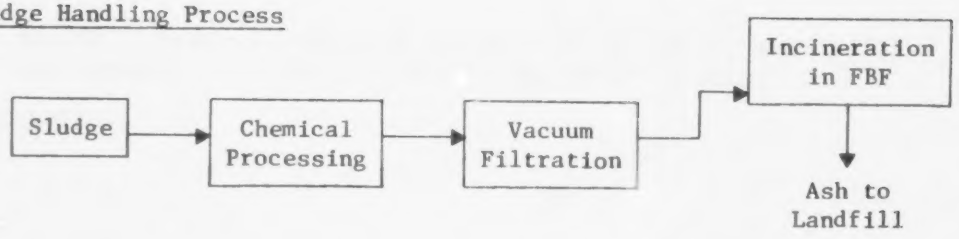
* Source: Consoer, Townsend & Associates, Nassau county, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

TABLE B-15

OPTION 1-B*

Sludge Handling Process


Sludge
Chemical Processing
Vacuum Filtration
Incineration in FBF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Cost ($/Ton Dry Solids)
10	†	76	154	230
50	†	59	96	155
100	†	49	82	131

Assumptions:

- Ash disposal costs are included in incineration costs.
- Vacuum filtration results in sludge cake of 20% solids.
- Fluidized bed incinerator includes combustion air preheater

---

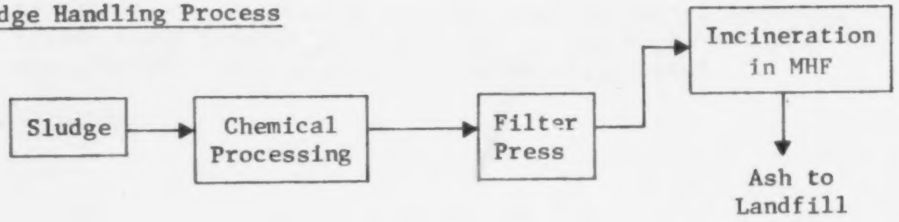
* Source: Consoer, Townsend & Associates, Nassau county, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

TABLE B-16

OPTION 2-A*

Sludge Handling Process


Sludge
Chemical Processing
Filter Press
Incineration in MHF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Costs ($/Ton Dry Solids)
10	†	101	104	205
50	†	59	73	132
100	†	47	70	117

Assumptions:

- Ash disposal costs included in incineration costs.
- Filter press results in sludge cake of 35% solids.

---

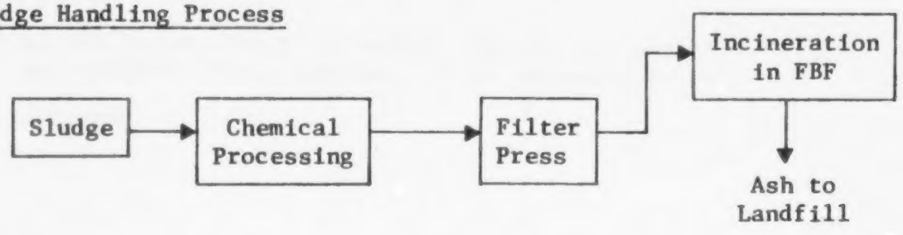
* Source: Consoer, Townsend & Associates, Nassau County, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

TABLE B-17

OPTION 2-B*

Sludge Handling Process


Sludge
Chemical Processing
Filter Press
Incineration in FBF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Costs ($/Ton Dry Solids)
10	†	101	139	240
50	†	59	81	140
100	†	47	66	113

Assumptions:

- Ash disposal costs included in incineration costs.
- Filter press results in sludge cake of 35% solids.
- Fluidized bed incinerator includes combustion air preheater.

---

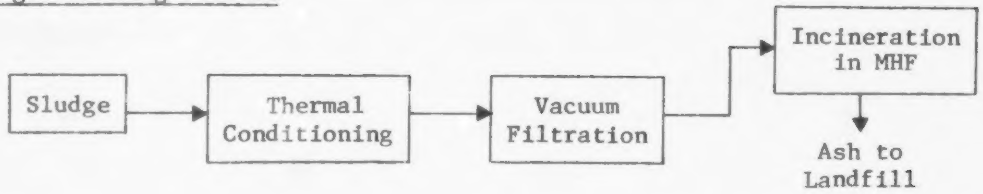
* Source: Consoer, Townsend & Associates, Nassau County, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

TABLE B-18

OPTION 3-A*

Sludge Handling Process


Sludge
Thermal Conditioning
Vacuum Filtration
Incineration in MHF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Cost ($/Ton Dry Solids)
10	72	54	104	230
50	38	37	73	148
100	34	33	70	137

Assumptions:

- Ash disposal costs included in incineration costs.
- Vacuum filtration results in sludge cake of 35% solids following thermal conditioning.
- Additional treatment costs for waste liquor are included in costs for thermal conditioning

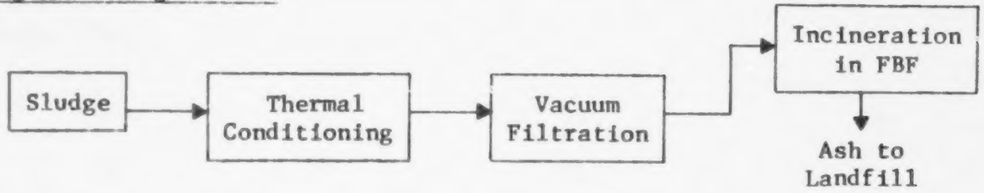
---

* Source: Consoer, Townsend & Associates, assau ounty, new york sludge management study.

TABLE B-19

OPTION 3-B*

Sludge Handling Process


Sludge
Thermal Conditioning
Vacuum Filtration
Incineration in FBF
Ash to Landfill

System Economics ($/Ton Dry Solids)

Sludge Input (TPD)				Total Cost ($/Ton Dry Solids)
10	72	54	139	265
50	38	37	31	156
100	34	33	66	133

Assumptions:

- Ash disposal costs included in incineration costs.
- Vacuum filtration results in sludge cake of 35% solids following thermal conditioning.
- Additional treatment costs for waste liquor are included in costs for thermal conditioning

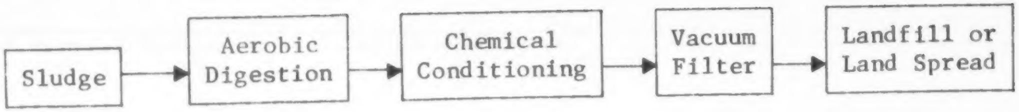
---

* Source: Consoer, Townsend & Associates, Nassau county, new york sludge management study.

TABLE B-20

OPTION 4*

Sludge Handling Process


Sludge
Aerobic Digestion
Chemical Conditioning
Vacuum Filter
Landfill or Land Spread

System Economics ($/Ton Dry Solids):

Sludge Input (TPD)					Total Cost ($/Ton Dry Solids)
10	59	†	76	26	161
50	40	†	59	14	113
100	41	†	49	11	101

---

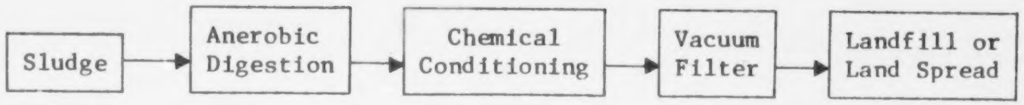
* Source: Consoer, Townsend & Associates, Naussau county, new york sludge management study, and Gordian Associates Incorporated

+ Included in dewatering costs.

TABLE B-21

OPTION 5*

Sludge Handling Process


Sludge
Anerobic Digestion
Chemical Conditioning
Vacuum Filter
Landfill or Land Spread

System Economics ($/Ton Dry Solids):

Sludge Input (TPD)					Total Cost ($/Ton Dry Solids)
10	31	†	76	26	133
50	19	†	59	14	92
100	16	†	49	11	76

---

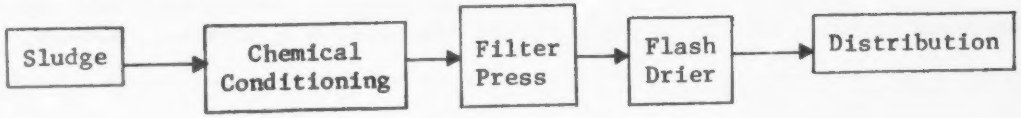
* Source: Consoer, Townsend & Associates, Naussau county, new york sludge management study, and Gordian Associates Incorporated

† Included in dewatering costs.

TABLE B-22

OPTION 6*

Sludge Handling Process


Sludge
Chemical Conditioning
Filter Press
Flash Drier
Distribution

System Economics ($/Ton Dry Solids):

Sludge Input (TPD)					Total Cost ($/Ton Dry Solids)
10	†	101	95	2	198
50	†	59	95	2	156
100	†	47	95	2	144

Assumptions:

Cost estimates do not reflect possible economies of scale in heat-drying operations.

---

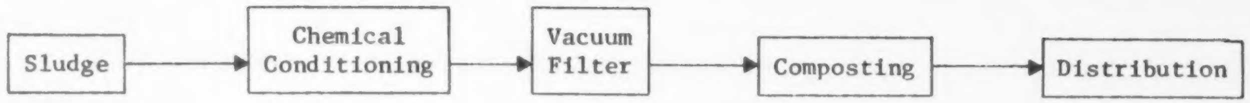
* Source: Consoer, Townsend & Associates, Nassau county, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

TABLE B-23

OPTION 7*

Sludge Handling Process


Sludge
Chemical Conditioning
Vacuum Filter
Composting
Distribution

System Economics ($/Ton Dry Solids):

Sludge Input (TPD)					Total Cost ($/Ton Dry Solids)
10	†	76	50	0	126
50	†	59	35	0	94
100	†	49	32	0	81

---

* Source: Consoer, Townsend & Associates, Nassau county, new york sludge management study, and Gordian Associates Incorporated.

† Included in dewatering costs.

APPENDIX C. SLUDGE DISPOSAL PLANNING ACTIVITIES OF OCEAN DUMPING COMMUNITIES

Permittee: Bergen County, New Jersey Sewerage Authority
Little Ferry, New Jersey

Status of Plans:

Codisposal has been examined as an alternative sludge disposal option to ocean dumping, and is seen as the most desirable system in the long run.

The County has been looking at the Union-Carbide Purox System (including electrical generation).

Composting will be pursued as an interim solution, until the codisposal system can be set up.

Permittee: Linden Roselle-Rahway Valley Sewage Authority,
New Jersey

Status of Plans:

The disposal alternative which has been chosen is sludge composting. The sludge from both Linden, N.J. and Rahway, N.J. would be composted together.

As a back-up to composting, two alternatives were examined:

1. Dewatering sludge to 28 to 32 percent moisture and landfilling, and
2. Codisposal of sludge and solid waste in refuse-fired modular combustion units, using low temperature pyrolysis.

The units would be fired directly with part of the solid waste from Linden. The refuse is currently landfilled at a site which is approximately the same distance away as the sewage treatment plant. All sorting would be done at the incinerator, during feeding. The major disadvantage to this proposal relates to anticipated air quality problems.

Some rough cost calculations have been developed to back up this alternative. However, the planning for codisposal is still in the pre-proposal stage, and the cost figures are not considered reliable at this time.

Permittee: Passaic Valley Sewerage Commission
Newark, New Jersey

Status of Plans:

Passaic Valley is in the process of developing feasibility studies. A number of codisposal projects are being examined, including:

1. Disposal of sewage sludge and solid waste through an industrial park operated by the New York-New Jersey Port Authority. The park would use sludge and solid waste to generate electricity and for resource recovery. The planning is still in the initial stages, and additional authority will have to be obtained.
2. Cooperation with the Essex County Improvement Authority (no details).
3. Public Service Electric and Gas. Co. (PSE&G): Passaic Valley has entered into a contract with PSE&G to determine the feasibility of burning sludge with coal in utility boilers.

Codisposal would be the preferred alternative, if one of the systems could be worked out in time for the 1981 deadline.

If not, the alternative would be sludge combustion in their own combustion facilities, since there is not enough land to compost. In either case, there is concern about compliance with the Clean Air Act.

Permittee: Middlesex County Sewage Authority,
New Jersey

Status of Plans:

Sludge incineratin in MHFs has been proposed as an alternative to ocean dumping.

Codisposal was evaluated and was considered a good alternative except for the institutional problems. These include:

1. Obtaining authority over solid waste;
2. Allocating costs and charges between solid waste and sewage treatment;
3. Cost of solid waste management would double (solid waste currently landfilled at $3 per ton);
4. Funding - sole purpose sludge management facilities are eligible for 75 percent federal, 8 percent state funding. Since solid waste facilities are not eligible for funding assistance, implementation of a codisposal system would depend on being able to propose a self-supporting solid waste facility that can be financed.

Permittee: Nassau County Department of Public Works
East Rockaway, New Jersey

Status of Plans:

Two codisposal options have been considered:

1. Participation in the Glen Cove codisposal project which is pending construction.
2. Use of sludge in Hempstead resource recovery project (pilot testing currently being conducted in Franklin, Ohio).

Pilot studes are also being conducted for composting and landfilling.

Permittee: Department of Environmental Facilities
Westchester County, New York

Status of Plans:

Westchester County has completed a 201 study which evaluated codisposal as an alternative to ocean dumping, but found that it was not economic due to transportation costs. According to their analyses, a codisposal option would be economically viable only if the incineration units were located close to the sewage treatment plant. However, air quality standards currently preclude the siting of incinerators in the area of the sewage treatment plant. Consequently, codisposal has been removed from consideration.

Currently plans for solid waste disposal recommend a resource recovery project, including generation of steam electricity. Current plans for sludge disposal involve composting. Both of these plans are being re-evaluated.

APPENDIX D. CODISPOSAL AT KREFELD, WEST GERMANY

CODISPOSAL AT KREFELD, WEST GERMANY

THE MODERN ALTERNATIVE TO OCEAN DUMPING OF SEWAGE SLUDGE*

By Klaus S. Feindler**

ABSTRACT:

Codisposal, especially when combined with energy and/or materials recovery, has proven to be a highly successful sewage sludge disposal technique in Europe. The Krefeld, West Germany Codisposal and Refuse Power Plant (C-RPP) is singled out for an in-depth review because of its highly advanced air pollution control system. West German emission standards for gaseous and particulate pollutions are discussed because, being considered as the most stringent in the world today, they had a profound influence on the design of the Krefeld C-RPP.

The special problems associated with complete combustion of sewage sludge are discussed, and mention is made of the U.S.-DOE grant for Krefeld which is to develop a complete balance of all pollutants which may result from the codisposal of municipal refuse and sewage sludge.

INTRODUCTION:

As a consequence of the U.S.-EPA ban on ocean dumping of municipal sewage sludge after 1981, alternative methods of disposal such as landfilling, composting and incineration are receiving renewed attention. This re-evaluation of older and previously established disposal methods coincides with the search for affordable and reliable methods of resource recovery from refuse.

It is, therefore, a logical approach to consider codisposal, i.e. the simultaneous processing of sludge and refuse in the same facility as a most promising alternative to ocean dumping. The generation of sludge and refuse alike is simply the direct result of our daily human activities. Their disposal is difficult, complex and costly, and, when viewed together with the concomitant issues of energy conservation and environmental protection, they tend to exert great pressures upon our society. This is particularly true in the urban areas of high population concentrations.

It is then no coincidence that several localities in the Mid-Atlantic States section of the U.S. are severely affected. The municipalities of Glen Cove, Nassau County, New York City, Newark, Philadelphia, and Westchester County, among others, are now clamoring to develop plans to comply with the EPA ban.

THE EUROPEAN CODISPOSAL EXPERIENCE:

Codisposal, even when combined with energy and/or materials recovery, is not an entirely new idea, since a number of such facilities were built in the U.S., in Asia and especially in Europe during the post-World War II period.

While U.S. facilities were generally small in size and largely unsuccessful in their operation, Europe, on the other hand, has produced a number of facilities in a rather wide range of sizes from 100 to 2,000 STPD (short tons per day) processing capacity. (See Reference 1)

Most significant is the fact that these European plants are operating successfully up to date, and therefore, it is appropriate to review the European codisposal experience and to determine its applicability to U.S. conditions.

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*Mid-Atlantic States Section of the Air Pollution Control Assoc. Semi-Annual Technical Conference, Hilton Gateway, Newark, N.J., April 27, 1979.

**President of Quantum Associates, a consulting firm concerned with resource recovery, and formerly Technical Director of Grumman Ecosystems Corporation.

The European codisposal facilities employ predominantly two successful technologies: co-composting and co-incineration. While composting is considered by most as a simple and inexpensive approach, it has demonstrated persistent marketing problems with its product materials. In most recent times, due to the progressive sewering of industrial and commercial neighborhoods, it has suffered greatly from the uncertainties which surround the fate of the heavy metals. Its critics have charged that through the agricultural use of compost produced by codisposal, heavy metals enter the food chain and endanger human health.

Incineration systems, by comparison, have proliferated in Europe in spite of the fact that they are both capital and energy intensive and unless properly designed, can have major environmental impacts.

Depending on planning objectives, codisposal plants of the co-incineration type range from mere disposal to full fledged resource recovery. The first approach simply uses refuse as the fuel to support destruction of the sludge; it often requires auxiliary fuel to compensate for moisture fluctuations in the sludge, and perhaps more significantly, in the refuse. These systems, while less sophisticated and capital intensive, face exceedingly higher operating costs, a fact which relates to their failure to recover energy and/or materials in order to generate off-setting revenues.

Examples are: Horsens, Reigate, Nieder-Uzwil

A second type provides boilers mounted over, or after, the basic incineration device called grates to use the thermal energy released during the combustion of refuse for steam production. The resulting steam, in turn, is then used to dry the sludge prior to its incineration or in some cases, pasteurize a portion of the feed sludge if it is to be used for agricultural purposes rather than for incineration. This type, due to flue gas cooling by the boilers, permits the use of more advanced air pollution control systems. However, this type is confined to small to medium sized installations.

Examples are: Dieppe, Deauville, Brive

Finally, a third type called "Codisposal - Refuse Power Plants," or C-RPP's, addresses the real needs of the large urban areas for nearby and centrally located facilities with high daily processing capacities. In these C-RPP's sludge is dried by direct contact with hot flue gases to the point of its conversion to a fuel which is also called "Sludge Derived Fuel," or SDF, which at a solid concentration of 95%, or more, and with a heating value of 8,000 to 10,000 Btu/Lb resembles low quality coal. This SDF is then fired in suspension in a zone downstream of, and separate from, the grate-fired refuse. This method of direct drying followed by suspension firing is also known as the DD-SF method.

Energy is efficiently recovered in the form of superheated steam if electrical power generation and/or district heating is contemplated. Ferrous metal is also recovered, either from the raw refuse itself, or after from the residue resulting from combustion, in order to further enhance the resource recovery aspects of these facilities. It is important to recognize the main distinction which separates C-RPP's from other codisposal/co-incineration approaches: thermal and/or electrical energy is exported for sale to external customers.

Table I lists the more important C-RPP's of the DD-SF type and indicates their technology status.

In this regard, the recent award by the City of Munich in West Germany (FRG), to build a large C-RPP of the DD-SF type must be viewed as a highly important development. Munich, a modern, large and highly commercial city, opted to reduce its various composting operations in favor of electrical power generation.

ENVIRONMENTAL CONCERNS ASSOCIATED WITH REFUSE POWER:

Several characteristics of major environmental significance must be associated with the operation of Refuse Power Plants in general, and with those of the C-RPP type in particular, regardless of the origin of their technology:

- safety and health hazards

- gaseous emissions
- liquid effluents

- residue stability

Of these four, the nature of gaseous emissions and their control should prove to be of particular interest to the participants of this MASS-APCA conference. This same point has received major attention from the regulatory agencies in Europe and especially from those in the FRG.

Just as Table 1 shows a preponderance of C-RPP development in the FRG, a similar table could be drawn up for plain RPP's. During the last two decades, the development trends in the FRG and the USA have become diametrically opposed. American investigators reported installed capacities for municipal incinerators at 50,000 STPD for 1970, 63,500 STPD for 1972 and 45,000 for 1976 respectively. Apparently, most U.S. municipalities prefer to shut down their incinerators rather than upgrade them for compliance with new pollution control regulations. (See Reference 2)

Just the opposite is true for the FRG, where during the last decade and a half a great deal of new capacity has been added. (See Reference 3)

For the 1973/76 period of comparison, the FRG could boast of approximately 35,000 STPD installed capacity versus some 45,000 STPD in the U.S., a fact which gains in importance, when one realizes the relative size of the populations served by these systems. Thus, 62 million Germans compared with 210 million Americans yield for 1973 a population factor of 3.4. Taking into consideration differences in the per-capita waste generation rates, 2.7 Lb/capita-day in the FRG versus 3.3 Lb/capita-day in the U.S., then at least in theory, up to 25.9 million people (42% of the total population) can be served by refuse incineration in the FRG versus only up to 27.3 million people (13% of the total population) in the U.S.

Following this line of reasoning, one would expect significantly higher emissions in the FRG, but just the reverse is true at least with two major pollutants, CO and particulates. Inspection of Table 2 will show in the column entitled "Emission Ratios USA/FRG" under "Incinerators" that FRG CO emissions are almost two orders lower and that FRG particulate emissions are at least one order of magnitude lower.

Both of these positive developments are the result of a long standing concern in the FRG for environmental protection which is evidenced by tough regulations which forced the development of advanced combustion techniques and/or air pollution control systems. Changes in the composition of waste streams are carefully monitored, and when new materials enter which cause the emission of new pollutants, then the regulations are amended accordingly. An example was the increase in HCl emissions which result from the burning of plastics delivered to the plants.

Table 3 reports on the measurement of gaseous emissions in selected European RPP's. While particulates are well controlled by the application of high performance electrostatic precipitators, the same cannot be said for HCl and SO_x.

The FRG Federal EPA took due notice of these adverse developments and responded by rewriting the emission standards for Refuse Power Plants. Table 4, "Refuse Power Plants: Emission Standards - West Germany vs. U.S.A." shows the results of T.A. Luft 1974 which is clearly more stringent than any standard presently in force in the U.S., or for that matter, anywhere else in the world.

The regulations for C-RPP's are even tougher because of the unique physical, chemical and biological characteristics which distinguish sludge from refuse: the first of these is the resistance of sludge to complete burnout even under the most favorable conditions of the three T's (temperature, time and turbulence).

Two investigators report these difficulties as follows:

> "...sludge cake which has been mechanically dewatered has a peculiar structure: it is a slime-like substance which is permeated by fibres and particles of different sizes. If sludge in this condition is exposed to heating, then the water contained in the outer layer will evaporate leaving behind a felt-like and strongly cohesive layer. While elastic and tough, this felt layer is a very poor thermal conductor, i.e. only little of the heat can penetrate in the still moist nucleus and effect its complete dry-out..." (Reference 4)
>
> "...little data is available on the thermal diffusibility of sludge, but assuming a value of $\alpha = 0.02\ mm^2/s$, the time taken for different thicknesses of cake can be estimated from 10 to 82 minutes for 20 to 60 mm. Consequently, the centers of large pieces of cake may still be decomposing while smaller pieces have completely burned out..." (Reference 5)

Since the mean residence time in modern RPP's firing high BTU refuse may be taken as a typical 45 minutes there is a danger that some large pieces, unless well broken up at the start, could pass through the system without decomposition. Such occurrences could lead to objectionable odors and microbial hazards.

Other problems could arise in areas where raw, unprocessed sludge is stored or transferred due to biological decomposition with accompanying odor and/or explosion hazards.

As can be gleaned from Table 5, TA Luft 1974 contains special requirements which deal with the unique problems of C-RPP's. An example is the storage and transfer of sludge which must occur under negative air pressure in a manner which permits combustion of any evolving gases and vapors at temperatures in excess of 800° C (1,472° F).

KREFELD C-RPP: THE MODEL FOR MODERN APC SYSTEMS:

One of the plants listed, the Krefeld C-RPP, was selected for an in-depth review as part of this paper, because its air pollution control system (APC) is the most advanced installed in any plant anywhere.

The Krefeld C-RPP is located on the west bank of the Rhine River in Krefeld, West Germany adjacent to the municipal sewage treatment plant. (See Figure 1). This plant, built by VKW and started up in 1975, is considered the most modern example of the codisposal type of plant because:

- it practices cogeneration with concomitant export of both electricity and district heat;
- it has the first full-scale combined precipitator/wet scrubber air pollution control systems (including desulfurization);
- it survived the tough challenges from the state licensing board in a heavily industrialized locality with non-attainment stature; and,

- it was the first plant which incorporated the patented Duesseldorf Roller Grate System, already proven in many refuse power plants elsewhere, with the HGS system.

The plant's current refuse processing capacity is 630 TPD (corresponding to a population of about 350,000); the projected design capacity is 1,100 TPD. The type of refuse processed is similar to that processed by the nearby Duesseldorf refuse power plant, shown on the following table entitled, "Classification of Wastes Processed by the Duesseldorf RPP." (Table 6).

In its final configuration, the plant will also consume 510 TPD of sludge cake at 26% TS concentration, from both sanitary and industrial services (corresponding to a combined population equivalent of 900,000). The plant is also equipped to fire up to 96 TPD of waste oil, as well as certain industrial wastes.

Figures 1A, 1B, 1C, 1D, 1E, 1F, and 1G further illustrate the Krefeld facility: Plot Plan, Plan View, Interfaces Between Municipal Services and Private Enterprise, Major Subsystems, Codisposal System with Energy Recovery, Flue Gas Purification Subsystem, and Sludge Processing Subsystem.

PLANT OPERATIONS:

The following discussion of the operation of the Krefeld C-RPP is keyed to the illustration, "Sectional View of Krefeld, West Germany, Codisposal and Refuse Power Plant," (Figure 2):

1. Refuse Processing:

The refuse handling subsystem starts with the dumping of refuse from packed trucks and other types of vehicles (1) into the storage pit (2). The storage pit at Krefeld is rather large, because it has extra capacity for long holiday weekends, as well as for expansion; at present, it can hold about seven to ten days worth of garbage. The cranes (3) lift the refuse and deposit it into the feedchute (4) by means of hydraulic feeders(5).

The refuse is then pushed onto the roller grates at (6), where drying takes place on the first roller and ignition on the second and third rollers. Most of the burning is completed on the third roller, and if not, on the fourth and fifth. The sixth roller is simply a safety provision to deal with hard to burn objects which occasionally find their way into the waste stream. This is a true counterflow system in that the refuse is moving downward and the fire and hot flue gases are moving upward.

At the end of the combustion chamber, the ash drops off into the ash quench tank. The gritlings fall through the rollers into the gritling hoppers beneath, and they are also added to the quench tank. All of the ash is then moved into the ash handling facility (7).

Steam is produced from the combustion of refuse in the boiler (9). This is a multi-pass boiler (first pass, radiation shaft; second pass, superheater; third pass, economizer).

The steam is taken out and passed through the turbo-alternators (16), which are back-pressure machines. The steam from the outlet side of the turbo-alternators goes into condensing-type heat exchangers. District heat is produced in these exchangers for pipeline transmission to the steam heat customer in a nearby industrial park.

From the condensing heat exchangers, the condensate is sent to the feed-water storage container (18). It is returned, via feed pumps, back into the boiler system.

The final design of the plant calls for three parallel processing systems At the present time, only two processing lines are installed. This is the traditional method in Germany, to enable adaptation to population growth. In line with this traditional approach, the plant was built with only two processing lines installed, and with enough space for a third one to be added. Presently, two back-pressure 1.4 MW turbo-alternators are installed. The third machine that will be installed, a condensation turbine, will be a 11.5MW unit, for a combined total plant generating capacity of close to 14.3 MW.

Behind the feedwater storage tank (18), there is a fuel oil-fired package boiler as well as the condensing heat exchangers, for district heat production. The service that is provided to the steam heat user is a non-interruptible heating service; consequently, in case of a shut-down of the refuse-fired boiler, the oil-fired package boiler serves as a back-up. The district heating capacity is on the order of 150 to 200 million Btu per hour final capacity.

2. Sludge Processing:

The sludge is first pumped up to the centrifuges (10). At present, a deck of four centrifuges is installed, and there is additional capacity to add two more. The purpose of centrifuging is to wring out some of the moisture and to bring up the solids content of the material to about 26% TS concentration. Prior to the point of entry into the centrifuges, polyelectrolytes are metered in as filtering or separating agents; since the object is to convert sewage sludge into a fuel, it is desirable to increase the solids content as much as is possible. There are two outputs from the centrifuges: the water that has been separated, which is returned to the sewage treatment plant; and the sludge cake in a still moist form. The sludge cake drops from the centrifuges down to an intermediate storage and transfer system (11), which transfers it onto various conveyors. These conveyors then lift the cake into a contact chamber at (12) where it is exposed to hot gases that are taken out of the boiler. This is called flash drying. The hot gases are removed from the radiation shaft of the boiler at (13), at roughtly 1,400° F to 1,500° F. They are syphoned off and brought down into the drying chamber, where they dry the sludge cake. The resulting cake is about 95% TS concentration and 5% water residual. At this point, the material is highly combustible. In fact, because the material is almost too combustible for storage, the system is designed to keep it flowing and to not let it accumulate. This cake drops down from the flash dryer into a hammer mill, known as the HGS mill, the lowest part of the system. The purpose of the HGS mill is to grind the sludge cake into a powder of high consistency; it must have a high degree of consistency to achieve steady and complete combustion. Mounted to the side of the HGS mill is the blower. The blower provides the pneumatic lift to propel the ground powder up through the sludge burner supply tubes (14). The suspension burners are located at the end of the tubes, approximately one-third of the way up in the radiation shaft. The sludge powder fuel, or SDF as it was previously characterized, is blown in through two horizontal suspension burners, igniting instantaneously and burning extremely well. The sludge is not fired together with the refuse; rather, each is fired separately. Only the flue gas stream coincides with the two processes. This is critical to maintaining complete burnout.

3. Air Pollution Control:

The flue gases pass through an electrostatic precipitator (19) for particulate removal, prior to entering the gas scrubbing building, via a fan (20). There are two major components in the gas scrubbing building, the first being the wet scrubbing system (21). This scrubbing system has two stages, and uses two different scrubbing fluids. The first stage of the scrubber removes the HCl and HF trace gases, with an acid solution as is evidenced by negative pH; this is done with a recirculating loop of liquid containing calcium hydroxide, or $Ca(OH)_2$.

The second stage works with an alkaline solution of a positive pH to scrub out the SO_2. This is accomplished by the addition of sodium hydroxide, or NaOH.

A portion of both scrubbing fluids is withdrawn for neutralization with lime and subsequent solids separation. The solids thus extracted, mostly salts, are transported to a special landfill while the liquid is returned to the nearby sewage treatment plant. This flue gas scrubbing system was originally developed by Peabody.

The second major component in the gas purification building is the reheat system. It works with a fan that draws in ambient air and with an air heater. Some steam is taken out of the plant to heat the ambient air. The hot air is then blended with the moist gases that are coming out of the scrubbers. As a result, it can be said that, under most meteorological conditions, there will be no visible plume from the plant. This system eliminates the plume problem often associated with wet scrubber use, and prevents condensation problems in the stack. In future plants, regenerative heat-exchangers made of glass tubes will be used to eliminate the loss of energy associated with steam heating.

APC TESTING:

The Krefeld C-RPP is presently undergoing modifications and expansion and several corrections were made in the scrubber part of its APC system. As a result, APC testing is incomplete and a cohesive data base has not been established yet.

However, the Kiel RPP in Northern Germany was the first plant to start up with a new APC system which also features the combination of electrostatic precipitators with wet scrubbers. There is no reason to believe that the Krefeld system would not perform equally well. In fact, performance of the Krefeld system in its final form is expected to surpass the Kiel results, especially with regard to SO_x removal because rather than one, two scrubbing fluids will be used, one of which has a particular affinity for sulfur.

Table 7 shows the results of APC testing at the Kiel RPP (see Reference 6). It is conceivable, however, that the Krefeld plant may deviate from Kiel in two respects due to its assigned task to fire sludge in addition to refuse. Particulate loadings into the precipitators are bound to increase. Also, there may be an upswing in the collection of metals either as oxides in the flyash, or as salts in the scrubber washing fluids.

Table 8 shows the concentrations of selected pollutants as they are removed by the scrubbing fluid. Success with the treatment of the resulting liquid effluents prior to their dumping into the municipal sewer is evidenced by the values presented in the middle column of this table.

DOE GRANT FOR RESEARCH AT KREFELD C-RPP:

Recognizing the limited data base presently available on the emission from C-RPP's employing the DD-SF method, and being keenly aware of the need to provide a complete and well documented data base before any large scale applications of this technology can be accomplished in the U.S., the US-DOE granted a research program in October, 1978 with the following technical objectives (see Reference 7):

- determine the minimum net energy usage requirements of the VKW codisposal process;
- prepare complete material and energy balances for the process in accordance with the system boundary limits described later herein;
- verify applicability of process to varying geography and varying types of waste in respect to impact on economic viability and energy requirements;
- evaluate environmental considerations related to acceptance and commercialization of the process; and,

- identify and address institutional barriers related to the requirement of cooperation between the public and private sector.

Of particular interest will be the effect which the variation of refuse, sludge and moisture residuals will have on the stability of power production as determined by boiler output parameters. More specifically, existing monitoring instrumentation will be augmented to generate sufficient data to provide:

- typical thermal and mass balances for refuse firing;
- typical thermal and mass balances for refuse and sludge firing;
- gross and net energy production, thermal and electrical; and,
- quality of energy production as shown by typical 24-hour, 7-day and monthly profiles for steam and electrical outputs.

A specific data collection program will be developed to provide a complete reading of those factors pertinent to the processes which impact the environmental acceptance of the system, and/or its ultimate commercialization. The testing will include data collection of all the gaseous and liquid effluents and solid residues, resulting from the combined firing of solid waste and sewage sludge for all operating conditions proposed for the system performance test. More specifically, a combination of grab sampling, wet chemistry analysis and on-line monitoring will be utilized to provide a complete data base which will include:

- simultaneous measurements of particulates HCl, HF, SO_2, and CO before the electrostatic precipitator, after the electrostatic precipitator, and after scrubbers;
- simultaneous measurement of water quality in the scrubber effluent and the water treatment systems, plus in the quench tank effluent;
- ambient air quality at some point down wind (if this can be done despite the closeness of other industry); and,
- micro-pollutant analysis, especially of heavy metals, with samples of raw garbage from feed chutes, sludge coming from the HGS mill, flyash and bottom ash respectively, boiler tube deposits, ash quench water, scrubber water, and stack effluents.

Critical importance will be attached to the determination of the fate of the heavy metals because of the concern expressed in many sectors of the United States environmental field with regard to alternative approaches to sludge disposal. Krefeld is most suitable for the pursuit of this aspect, because of the presence of significant amounts of sludge derived from industrial waste waters.

The test program will provide a preliminary assessment of the environmental considerations of the DD-SF codisposal process. Measurement methods and test equipment will be responsive to the requirements of the Reference Test Methods promulgated by the United States Environmental Protection Agency.

CONCLUSION:

The urgency to identify alternative approaches to dumping and landfilling carries with it the need to identify alternatives that reflect a more prudent use of energy, in a more cost-effective manner. The European experience, through technology transfer, can provide such an alternative at acceptable risks.

The codisposal of sewage sludge with solid waste is now being successfully practiced in Europe. The European technology for codisposal can be considered proven and operational both in terms of significant scale and longevity of operations. Attempts in the United States to develop comparable systems have not been successful, to date. Among competing technologies, the DD-SF method of thermal sludge processing as practiced in Krefeld has proven superior. Also, the European experience has shown codisposal and its attendant SDF production to be beneficial in both energy and economic terms. By utilizing solid waste as an alternative fuel in the place of oil and gas, the operation of codisposal facilities has resulted in a meaningful reduction in energy consumption which benefits both the local government and the national economy. This holds especially true for the very large plants serving metropolitan areas.

Based on this experience, many communities in the United States are now investigating the establishment of codisposal facilities. They are being hampered in this effort, however. In the absence of any prolonged testing, no extensive data base exists today on two key aspects: energy performance and efficiency and environmental impact, particularly of heavy metals emissions. The availability and use of such data is essential to project development in the United States.

The DOE program, it is hoped, will provide the long range answers to most, or perhaps even all of these questions. It is regrettable that this program will not yield tangible results in time to affect the implementation of compliance programs presently being planned by a number of large Eastern municipalities which are traditionally being involved with ocean dumping.

It would be prudent for the U.S. EPA to consider permit extensions for municipalities which are seriously committed to finding long term solutions to the sludge problem, such as C-RPP's which by their very nature may require a 3 to 4 year planning and construction cycle.

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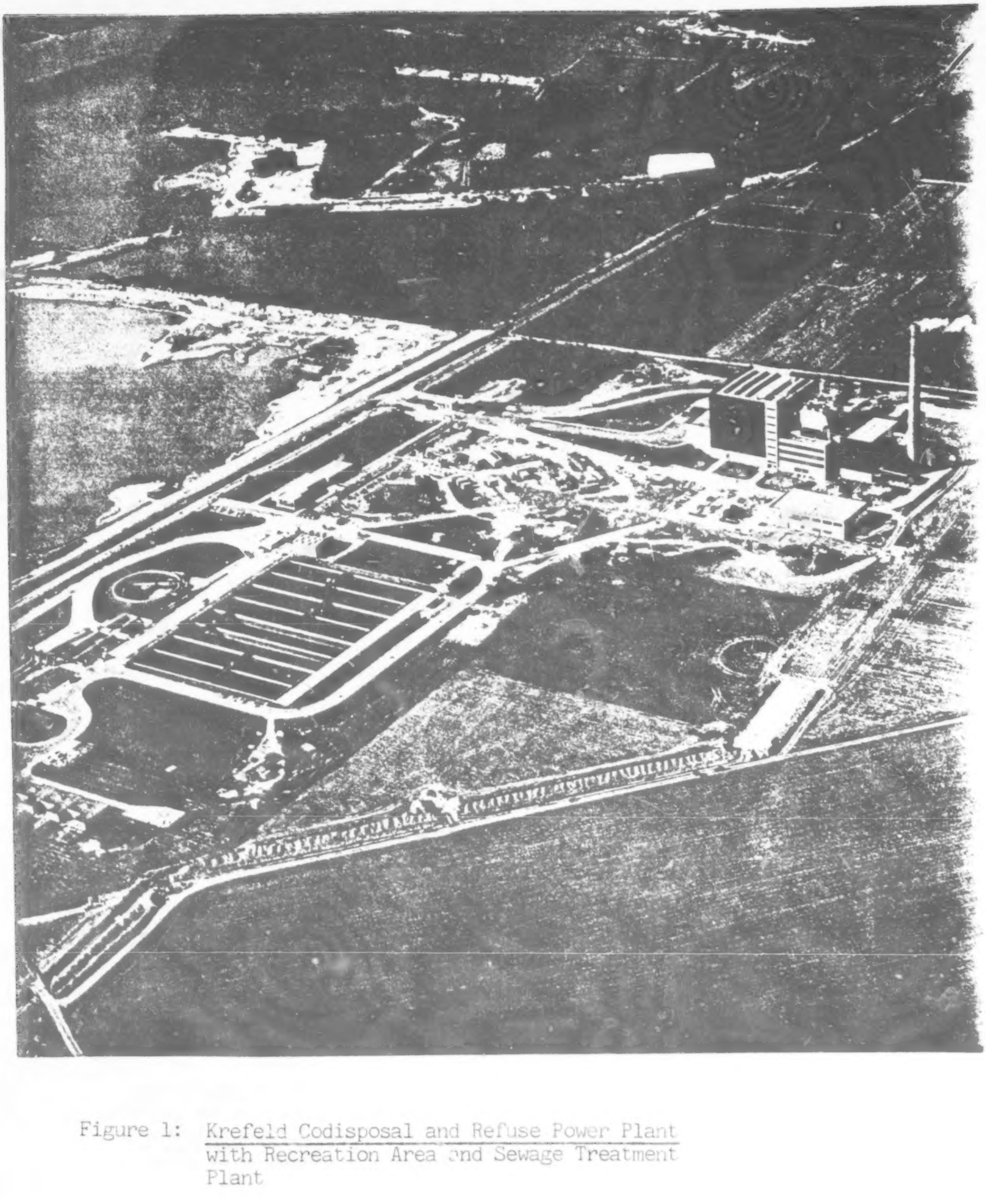

Figure 1: Krefeld Codisposal and Refuse Power Plant with Recreation Area and Sewage Treatment Plant

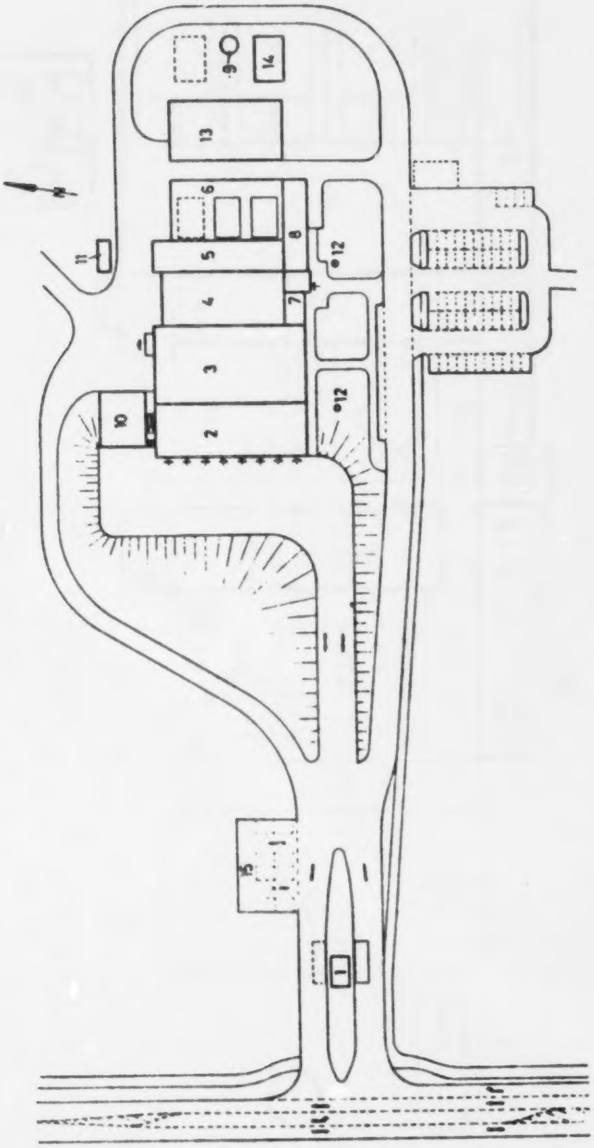
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Figure 1A: Krefeld Codisposal Plant: Plot Plan

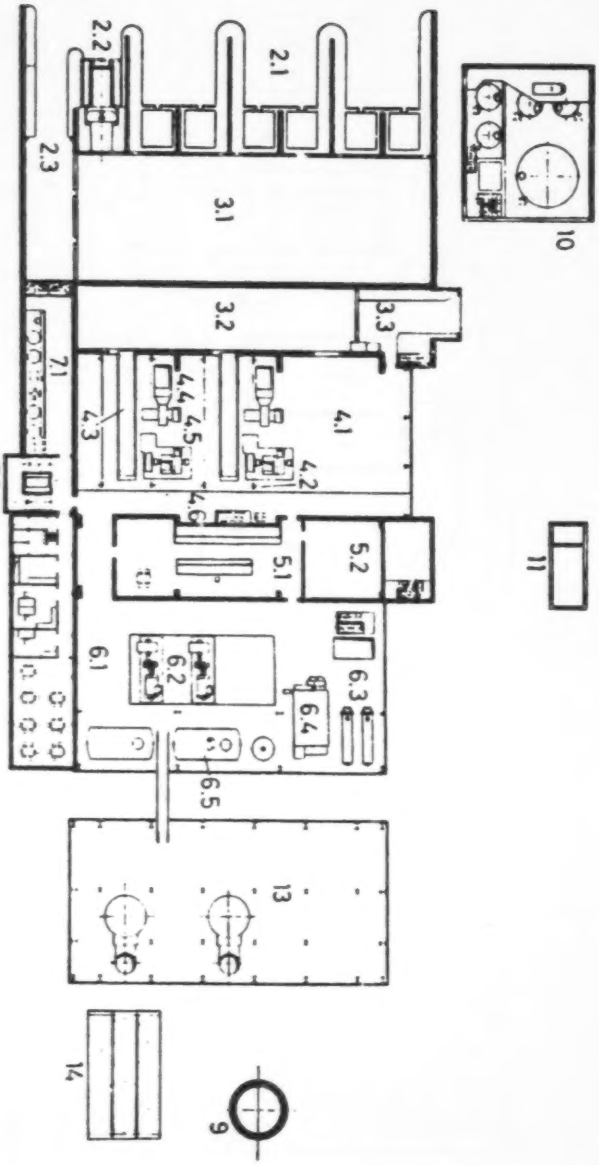
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Figure 1B: Krefeld Codisposal Plant: Plan View

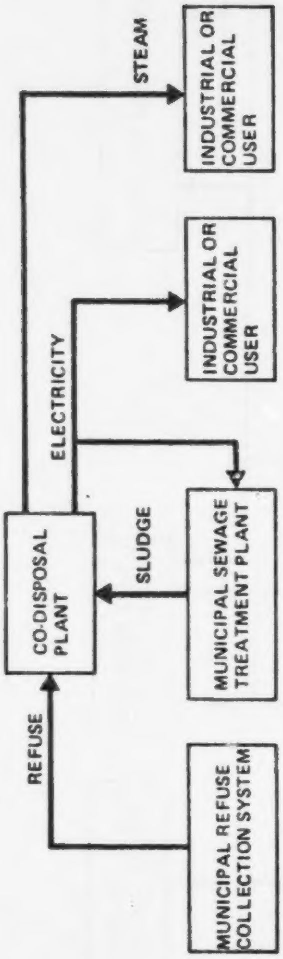

MUNICIPAL REFUSE COLLECTION SYSTEM
REFUSE
CO-DISPOSAL PLANT
SLUDGE
MUNICIPAL SEWAGE TREATMENT PLANT
ELECTRICITY
INDUSTRIAL OR COMMERCIAL USER
STEAM
INDUSTRIAL OR COMMERCIAL USER

Figure 1C:
Interfaces Between Municipal Services and Private Enterprise

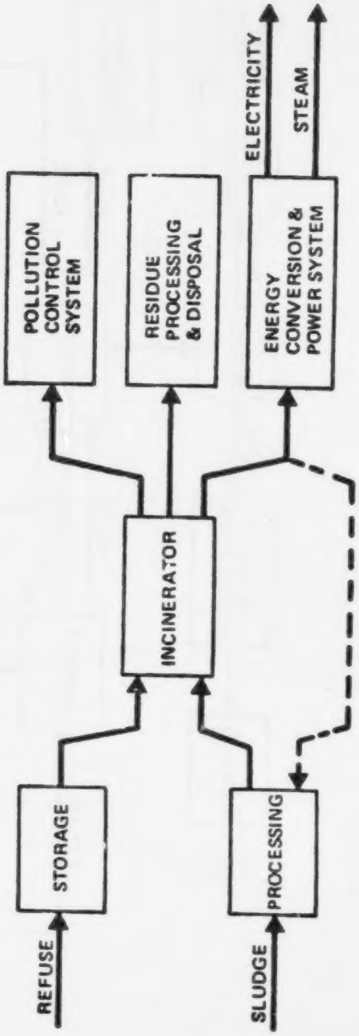
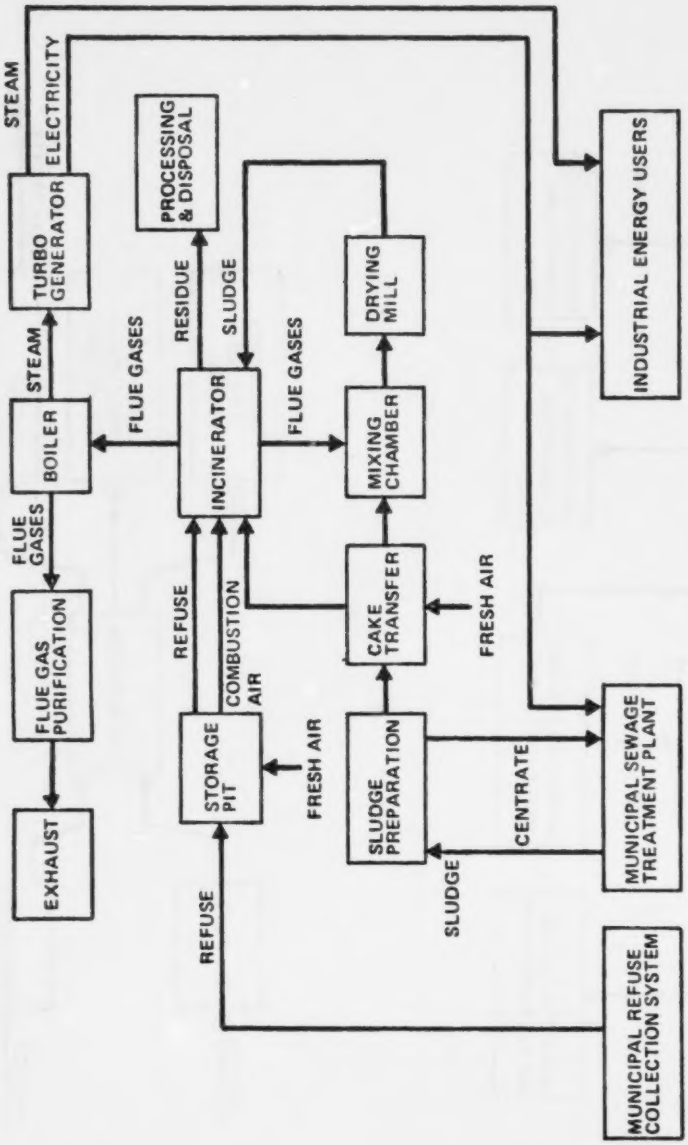

REFUSE
STORAGE
SLUDGE
PROCESSING
INCINERATOR
POLLUTION CONTROL SYSTEM
RESIDUE PROCESSING & DISPOSAL
ENERGY CONVERSION & POWER SYSTEM
ELECTRICITY
STEAM

Figure 1D:
Major Subsystems


STEAM
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TURBO GENERATOR
PROCESSING & DISPOSAL
STEAM
FLUE GASES
RESIDUE
SLUDGE
DRYING MILL
INDUSTRIAL ENERGY USERS
BOILER
INCINERATOR
FLUE GASES
MIXING CHAMBER
FLUE GASES
FLUE GAS PURIFICATION
REFUSE
COMBUSTION AIR
CAKE TRANSFER
FRESH AIR
STORAGE PIT
FRESH AIR
SLUDGE PREPARATION
CENTRATE
MUNICIPAL SEWAGE TREATMENT PLANT
EXHAUST
SLUDGE
REFUSE
MUNICIPAL REFUSE COLLECTION SYSTEM

Figure 1E:
Codisposal System with Energy Recovery

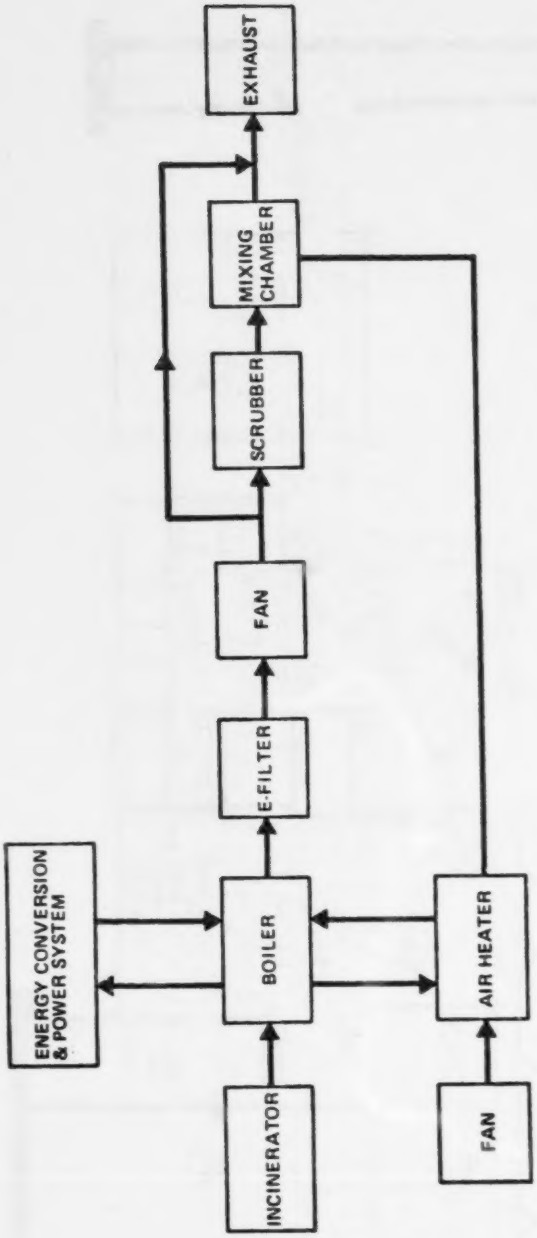
INCINERATOR
FAN
ENERGY CONVERSION & POWER SYSTEM
BOILER
AIR HEATER
E-FILTER
FAN
SCRUBBER
MIXING CHAMBER
EXHAUST

Figure 1F:
Flue Gas Purification Subsystem

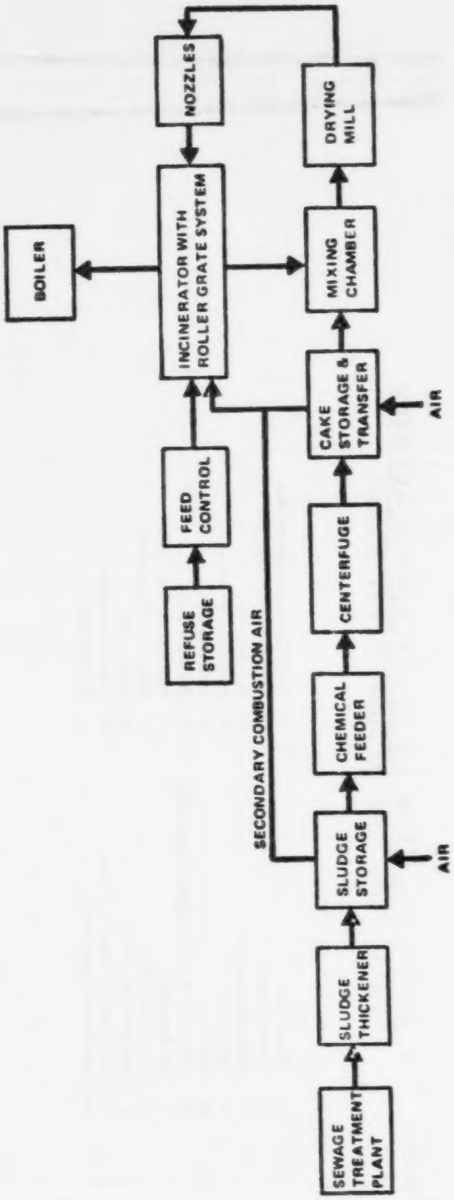
SEWAGE TREATMENT PLANT
SLUDGE THICKENER
SLUDGE STORAGE
AIR
SECONDARY COMBUSTION AIR
CHEMICAL FEEDER
CENTERFUGE
REFUSE STORAGE
FEED CONTROL
CAKE STORAGE & TRANSFER
AIR
BOILER
INCINERATOR WITH ROLLER GRATE SYSTEM
MIXING CHAMBER
DRYING MILL
NOZZLES

Figure 1G:
Sludge Processing Subsystem

Figure 2 : Sectional View of Krefeld, West Germany
Codisposal and Refuse Power Plant

1. Tipping Floor
2. Refuse Storage Pit
3. Refuse Charging Crane
4. Feed Hopper
5. Ram Feeder
6. Roller Grate System for Refuse Incineration
7. Ash Storage Pit
8. Ash Removal Crane
9. High Performance Boiler
10. Centrifuges for Dewatering Sludge
11. Sludge Cake Storage Containers
12. Sludge Drying and Grinding Mill
13. Flue Gas Recirculation Duct
14. Sludge Burners
15. Central Control Room
16. Turbogenerators
17. Machinery Crane
18. Feedwater Storage Tanks
19. Electrostatic Precipitators
20. Exhaust Fan
21. Flue Gas Scrubbers
22. Exhaust Stack

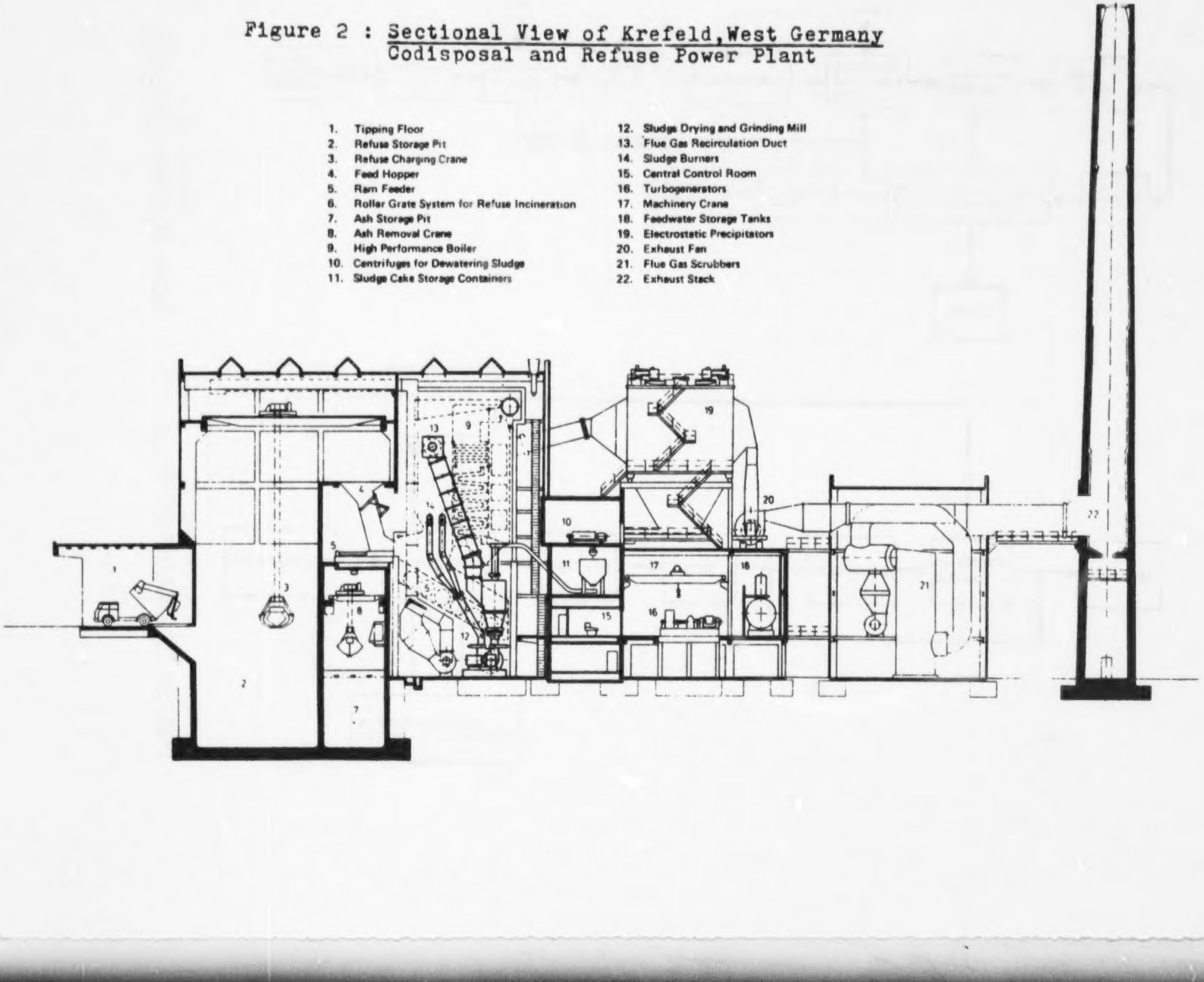

Table #1: European and Asian C-RPP's of the DH-SF Type

Page 1 of 2

Plant	Startup	Design Processing Capacities				Steam Conditions	
		Processing Lines	Refuse	Sludge		Temperature	Pressure
Name	Year	stph	STPD	WSTPD	DSTPD	°F	psig
Essen-Karnap	1961/65	5 x 22.0	1,500	1,800	1,035	950	1,421
Solothurn	1973	2 x 11.0	528	(Planning Stage)		707	551
Krefeld	1975/80	2 x 13.2 1 x 19.4	1,100	510 (@26%TS)	133	707	363
Fürstenfeldbrück	1975	1 x 6.6	158	52 (@45.7%TS)	24	Sat.	341
Ingolstadt	1977/81	2 x 8.3 1 x 8.3	594	159 (@25%TS)	40	(Retrofit Planned)	
Bamberg	1977/81	2 x 6.6 1 x 6.6	475	150 (@40%TS)	74	Sat.	370
Kyoto	1979	3 x 16.5	1,188	(Planning Stage)		770	1,088
Bielefeld	1981	3 x 17.6	1,270	555 (@45%TS)	250	752	580
Munich III	1981	2 x 24.2	1,162	634 (@25%TS)	475	752	580

Table #1 (cont.)

Plant	Energy Output	APC System	Technology Origin
Name	Electricity/Steam MW	Components	
Essen-Karnap	5 x 50 = 250	ESP's	Deutsche Babcock
Solothurn	1 x 8 = 8	ESP's	Von Roll
Krefeld	2 x 1.4 + 1 x 4.25 = 7.1 or 1 x 11.5 = 11.5 and/or 200 x 10^6 Btu/hr	ESP's + M.S. - Wet Scrubbers	VKW
Fürstenfeldbrück	Housekeeping and Process Needs	ESP + Wet Scrubber	Keller Peukert/VKW
Ingolstadt	Housekeeping and Process Needs	ESP's + Wet Scrubbers	Widmer + Ernst
Bamberg	Housekeeping and Process Needs	ESP's + Wet Scrubbers	Keller Peukert/VKW
Kyoto	1 x 4 = 4	ESP's	Kawasaki/VKW
Bielefeld	1 x 30 = 30	ESP's + Wet Scrubbers	Widmer + Ernst
Munich III	1 x 23 = 23 or 1 x 26 = 26	ESP's + Scrubbers	VKW/Martin

Table 2 :

SOURCES OF AIR POLLUTION: USA vs. FRG in 1973

	USA EMISSIONS (1)			FRG EMISSIONS (2)			EMISSION RATIOS USA/FRG (3)		
		INCINERATORS			INCINERATORS				
POLLUTANT	TOTAL IN MT/Y	MT/Y	% OF TOTAL	TOTAL IN MT/Y	MT/Y	% OF TOTAL	TOTALS	INCINERATORS	MAJOR CONTRIBUTORS
Carbon Monoxide, CO	91,500,000	254,000	0.278	8,000,000	1,000	0.013	11.44	254.0	Transportation
Sulfur Oxides, SO_X	32,300,000	10,900	0.034	4,000,000	12,000	0.300	8.08	0.9	Power Plants, Diesel-powered transportation
Nitrogen Oxides, NO_X	20,900,000	14,500	0.069	2,000,000	5,000	0.250	10.45	2.9	Transportation, Power Plants, Steel Industry
Hydrocarbons, HC	28,400,000	10,900	0.038	2,000.000	2,000	0.100	14.20	5.5	Transportation Miscellaneous
Hydrogen Chlorides, HCl	N.A.	N.A.	N.A.	> 17,000(4)	8,000	<47.059	N.A.	N.A.	Process Industry, Power Plants, Incinerators
Fluorides, HF	N.A.	N.A.	N.A.	40,000	50	0.125	N.A.	N.A.	Process Industry
Offensive Odors	N.A.	N.A.	N.A.	N.A.	None	N.A.	N.A.	N.A.	Various Industries, Landfills
Particulates	19,900,000	104,300	0.524	4,000,000	2,000	0.050	4.98	52.2	Power Plants, Various Industries
TOTALS	> 193,000,000	> 394,600	0.204	> 20,057,000	30,050	0.150	9.62	13.1	

NOTES:
(1) Source: U. S. Environmental Protection Agency, National Emissions Data Center
(2) Source: "Wohin mit den Abfällen? Umweltschutz durch Müllverbrennung" ("Environmental Protection Through Refuse Incineration")
(3) For comparison in 1973 the population ratio was USA/FRG = 210.4/62.0 = 3.39
(4) Power plants account for another 8,500 MT/Y in the FRG. The process industry is strongly suspected as a major contributor, but the amounts involved are difficult to estimate.

Table #3 : Average Gaseous Emissions(1) from European RPP's and C-RPP's

Plant		Paris Issy	Paris Ivry	Zürich Hagenholz	Zürich Hagenholz	Uppsala
Units Tested	Test	1 - 4	1;2	1;2	3	1 - 4
Test Date:	Point	Feb. 77	Jul. 77	(?)	73	Apr. 74
Particulates	Boiler	N.M.(2)	N.M.	N.M.	N.M.	731
(mg/Nm^3)	ESP	46(2)	117	72	42	21
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
$SO_2 + SO_3$	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
(mg/Nm^3)	ESP	132	132	219	220	190
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
HF	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
(mg/Nm^3)	ESP	N.M.	N.M.	N.M.	11	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
HCl	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
(mg/Nm^3)	ESP	1,416	1,050	531	840	78
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
$NO + NO_2$	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
(mg/Nm^3)	ESP	135	171	N.M.	N.M.	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
Data Source		Battelle	RPA	Battelle	Battelle	Battelle

Table # 3 (cont.)

Page 2 of 3

Plant		Rosenheim	Rosenheim	Düsseldorf	Düsseldorf	Düsseldorf
Units Tested Test Date	Test Point	1 Oct. 65	1 May 68	1 - 4 67/69	1 - 4 70	1 - 4 71
Particulates (mg/Nm^3)	Boiler	6,900	6,400	12,087	N.M.	N.M.
	ESP	77	71	39	N.M.	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
$SO_2 + SO_3$ (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	2,486	1,259	918	855	738
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
HF (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	N.M.	5	N.M.	N.M.	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
HCl (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	712	576	778	970	948
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
$NO + NO_2$ (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	N.M.	N.M.	N.M.	N.M.	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
Data Source		VGB	VGB	Operator	Operator	Operator

Table # 3 (cont.)

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Plant		Düsseldorf	Stockholm Högdalen	Stockholm Högdalen	Krefeld	Kiel
Units Tested	Test	1 - 5	1;2	(?)	1;2	1;2
Test Date	Point	73 - 77	June 72	Nov. 74	76	76
Particulates (mg/Nm^3)	Boiler	N.M.	2,700	N.M.	N.M.	8,330
	ESP	N.M.	216	N.M.	N.M.	184
	Scrubber	N.A.	N.A.	N.A.	N.M.	19
$SO_2 + SO_3$ (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	505	250	1,987	450R	550
	Scrubber	N.A.	N.A.	N.A.	N.A.	250
HF (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	9	5	0.3	N.M.	9.3
	Scrubber	N.A.	N.A.	N.A.	N.A.	.4
HCl (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	1,000	629/777	1,266	1,257 R(3)	1,170
	Scrubber	N.A.	N.A.	N.A.	1,183 R+S	24
$NO + NO_2$ (mg/Nm^3)	Boiler	N.M.	N.M.	N.M.	N.M.	N.M.
	ESP	9	125	N.M.	216 R	N.M.
	Scrubber	N.A.	N.A.	N.A.	N.A.	N.A.
Data Source		Battelle	Avloppsverken	R. Nilsson	VKW	Operator

Notes:
1) Data is not always correct to the same reference conditions.
2) N.M. denotes parameter was not measured, N.A. means "not applicable," i.e. allowable emissions were not specified by licensed board,and therefore, no specific removal equipment was provided.
3) R denotes "refuse firing only;" R + S denotes "refuse and sludge firing."

Table #4:

REFUSE POWER PLANTS: EMISSION STANDARDS
WEST GERMANY vs. U.S.A.

PARAMETER	UNITS	ALLOWABLES		
		W. GERMANY (1a)(1b)	U.S.A. (3)	MASS. (4)
PARTICULATES	mg/Nm^3	100	180 (5)	115 (6)
HCl	mg/Nm^3	100	--	--
SO_2	mg/Nm^3	100 (2)	--	--
HF	mg/Nm^3	5	--	--
CO	mg/Nm^3	1,000	--	--
OPACITY	Ringelmann No.	1	--	1
MIN. TEMPERATURE	°C @ 0.3 sec	800	--	--

NOTES:
(1a) Source: TA Luft 1974 (Technische Anleitung zur Reinhaltung der Luft)
(1b) Reference Conditions: 0° C, 1030 mbar, 11% Vol. 0, moist gases
(2) Krefeld C-RPP and Hamburg RPP, not general requirement yet.
(3) Source: EPA Regulations on Standards of Performance for New Stationary Sources, as amended, 1975; Subpart E - Standards of Performance for Incinerators.
(4) Source: Massachusetts Air Pollution Control Regulations, 1972 Section 2.5.3
(5) Corresponds to 0.08 gr/dscf
(6) Corresponds to 0.05 gr/dscf

TABLE 5

May 31, 1979
Sheet 1 of 2

Mandatory Air Pollution Control Criteria for West German RPP's and C-RPP's (1) (2) (3)

Translated and Edited by Klaus S. Feindler*

1. The refuse storage pit must be kept below atmospheric pressure; the air which is drawn off shall be fed to the furnace. In the case of facilities intended for continuous operation, if the furnace is temporarily shut down, (for example, as the result of equipment malfunction), then the drawn-off air must be vented via the stack.

2. If liquid wastes are to be burned in addition to solid wastes, then these liquid wastes must be stored in closed containers. Transfer points with openings need to be equipped with suction devices such that the drawn-off air can be fed into the furnace.

3. The facilities must be equipped with a supplemental firing system.

4. All facilities must be connected to a stack.

5. The facilities must provide an afterburning chamber which opens into the combustion chamber, or is located downwind from it, so that waste gases can be retained in it for at least 0.3 seconds at a minimum temperature of 800° C. (1,472° F) and a minimum O_2 concentration of 6% by volume. This temperature is to be monitored by continuously recording instrumentation. The facilities must be laid out in such a manner that waste charging is only possible when this minimum temperature has been reached. A supplemental burner needs to be installed in the afterburning chamber which turns on automatically as soon as the temperature drops below the allowable minimum. Such afterburning needs to take place even if the facility is not in operation and the air drawn off the refuse storage pit is vented through the afterburning chamber.

6. The facilities shall be operated in such a manner that the highest degree of burnout possible is guaranteed for the waste gases and any fermentable components entrained in them.

7. Particulate emissions in the wet waste gases may not exceed 100 mg/m^3 corrected for an O_2 content of 11% by volume and referred to standard conditions of temperature and pressure (0° C and 1,013 mbar or 32° F and 14.69 psia)

8. The opacity in the waste gas plume shall be less than the value of number 1 on the Ringelmann scale.

9. The criteria of paragraphs 6 and 7 shall be maintained even during periods of soot blowing from the boilers.

*Formerly Technical Director with Grumman Ecosystems Corporation and presently a Resource Recovery Specialist with Quantum Associates.

Sheet 2 of 2

10. Anorganic emissions in the moist waste gases may not exceed the following values:

    Chlorine compounds (expressed as $C2^-$) = 100 mg/m^3

    Fluorine compounds (expressed as F^-) = 5 mg/m^3

    These values are to be corrected for an O_2 content of 11% by volume and referred to standard conditions of temperature and pressure.

11. Carbon monoxide concentrations in the moist waste gases may not exceed 1,000 mg/m^3 corrected for an O_2 content of 11% by volume and referred to standard conditions of temperature and pressure.

12. Instrumentation is to be provided for the continuous recording of the concentrations of particulates, anorganic chlorine compounds and fluorine compounds in the effluent waste gases.

13. Polychlorinated biphenyls (PCB's), or materials containing PCB's can only be burned in facilities especially equipped for such furnaces: i.e. furnaces which can maintain a minimum temperature of 1,200° C/ (2,192° F).

14. Organic compounds (essentially unburnt hydrocarbons) as part of effluent vapors or gases are classified according to their chemical structure in 3 classes which range in their allowable emissions from 20 to 300 mg/m^3. In case several classes are present, the sum of all organic emissions shall not exceed 300 mg/m^3.

Notes: (1) Source: TA Luft 74 (Technische Anleitung zur Reinhaltung der Luft, or Technical Guidelines for the Protection of Air Purity) and GMBL 1974 of August 28, 1974, pages 426 and 452.

(2) Covers class 2 facilities which are to burn, completely or in part, predominantly wastes from households, or similar materials, with a mass flow capacity in excess of 0.75 mtph (0.83 stph).

(3) The burning of "other wastes" (i.e. industrial and hazardous wastes) is covered elsewhere in the guidelines; they are omitted here for reasons of brevity.

Table 6 : Classification of Wastes Processed by the Duesseldorf RPP

WASTE CLASSIFICATION	ANNUAL THROUGHPUT	
	MT	%
1. Residential Refuse (Burned as Received)		
1a. Collection by Host City	167,472	56.2
1b. Collection by Outside Municipalities	32,530	10.9
1c. Combined Collections	200,002	67.1
2. Industrial & Commercial Refuse (Burned as Received)	66,368	22.3
3. Bulky Wastes (Burned after Shredding and Mixing)	19,624	6.6
4. Yardwaste & Sweepings (Burned as Received)	9,210	3.1
5. Dirt with Oil Contamination (Burned as Received)	2,213	0.7
6. Automobile Tires (Burned after Shredding and Mixing)	767	0.3
TOTAL Σ 1-6	298,184	100.0

Table 7:

REFUSE POWER PLANTS
PERFORMANCE OF ESP AND WET SCRUBBER AT MVA KIEL(1)

PARAMETER	UNIT	HCl(2)	HF(2)	SO_2	PARTICULATES(3)
INFLUENT TO ESP	mg/Nm^3	-	-	-	5,200 - 13,000
INFLUENT TO SCRUBBER	mg/Nm^3	1,170	9.3	550	89 - 267
EFFLUENT FROM SCRUBBER	mg/Nm^3	24	0.4	250	15 - 26
REMOVAL EFFICIENCY					
- AVERAGE(2)	%	98	96.0	55	85 - 90
- MINIMUM	%	96	94.0	46	-
- MAXIMUM	%	99	98.0	59	-
NUMBER OF MEASUREMENTS		24	24.0	20	4

NOTES: (1) Source: Dipl. Ing. Helmut Grimm of MVA Kiel

(2) Corrected to 11% O_2 by volume

(3) System was intentionally overloaded by changing from design rate of 5.5 stph to test rate of 8.35 stph; i.e. the system carried a 51% overload by refuse weight.

Table 8 :

REFUSE POWER PLANTS: SCRUBBER WATER POLLUTANTS AT MVA KIEL (1)

PARAMETER	UNITS	RECIRCULATION LOOP	BLEED LOOP (2)	ALLOWABLES (HUSMANN) (3)
CHLORIDES	mg/l	[6,000] [7,000]	2,000	-
CHROMIUM (TOTAL)	mg/l	0.20	0.05	4.00
COPPER	mg/l	1.15	0.15	3.00
MERCURY	mg/l	0.30	0.20	-
NICKEL	mg/l	0.57	0.20	5.00
SULFATES	mg/l	145.	233.	400.
TIN	mg/l	1.80	1.00	-
ZINC	mg/l	33.54	2.50	5.00

NOTES:

(1) Source: Dipl. Ing. Grimm of MVA Kiel

(2) After neutralization, and after sludge settling

(3) Arbeitsblatt #90, December 1970:
"Hinweise für das Einleiten von Abwasser aus gewerblichen u. industriellen Betrieben in eine Öffentliche Abwasseranlage"

APPENDIX E. LIST OF ABBREVIATIONS

LIST OF ABBREVIATIONS

APC	Air pollution control
BTU	British thermal unit
CCCSD	Central Contra Costa Sanitary District
CCSL	Carlton County Sanitary Landfill
CDM	Camp, Dresser and McKee, Inc.
DDCSL	Duluth Disposal Company Sanitary Landfill
DOE	U.S. Department of Energy
ENR	Engineering News Record
EPA	U.S. Environmental Protection Agency
FBF	Fluidized-bed furnace
FOB	Free on board
GO	General obligation
MC	Metropolitan Commission (Minneapolis-St. Paul)
MGD	Million gallons per day
MHF	Multiple-hearth furnace
MSS	Municipal sewage sludge
MSW	Municipal solid waste
MWCC	Metropolitan Waste Control Commission (Minneapolis-St. Paul)
NCRR	National Center for Resource Recovery
O & M	Operating and maintenance
PL 95-217	Clean Water Act Amendments of 1977
RCRA	Resource Conservation and Recovery Act of 1976
RDF	Refuse-derived fuel

SWPF	Solid waste processing facility
TCMA	Twin Cities Metropolitan Area
TPD	Tons per day
USDA	U.S. Department of Agriculture
WLSSD	Western Lake Superior Sanitary District
WWTP	Waste water treatment plant

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